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CONTRIBUTIONS

TO THE

SCIENCE OF HYDRAULIC ENGINEERING.

BY

EWD. FONTAINE,

PROFESSOR OF THEOLOGY AND NATURAL SCIENCE, MEMBER OF THE NEW YORK HISTORICAL SOCIETY, THE HISTORICAL SOCIETY OF MARYLAND, &c., AND OF THE ACADEMIES OF SCIENCE OF BALTIMORE, NEW ORLEANS, &c., AUTHOR OF "HOW THE WORLD WAS PEOPLED," &c.

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PREFACE.

I thought first of presenting the following contributions to the science of Hydraulic Engineering in the usual form of a plain methodical work for the instruction of students. But certain objections suggested by the recollection of my painful experience in the study of such treatises inclined me to give it to them in a composition which they will find more entertaining, and I hope equally instructive.

It is usual for text-books, and especially those of the exact sciences for the use of schools, to be divested of all the adornments of fancy. They aim at conciseness of style, and smallness of bulk. Such books may be cheap and marketable, but they are exceedingly dry and uninteresting; and they are difficult to understand and easily forgotten. Arithmetics, Algebras, Geometries, and the text-books on Civil and Military Engineering, and Navigation, and even treatises on the most sublime of all the physical sciences, *Astronomy*, used in our Military and Naval Academies, and all our institutions of learning, almost without an exception are of this dry, stony, and icy character, utterly devoid of every tint and trait of beauty which can attract the attention, charm the imagination, and impress the memory. When I was a youth I studied Horner's Anatomy; and the ludicrous plainness of his descriptions of the wonderful details of the material tenement of the immortal soul amused me. But why should not a book descriptive of bones be "dry as a bone"? And what room for "the play of fancy" is there in a treatise on "the theory of curves"? The writers of such works are hardly capable of giving a correct answer, for they are usually totally devoid of the poetical faculty, as the imaginative youths who are forced to study them know to their sorrow. It is generally the severest toil and torture of their ardent young lives; and through all their future years the most brilliant geniuses among them look back upon the ordeal of their mathematical course with horror. The fault is in the writers of the text-books, and not in the noble sciences which they dissect, skeletonize, and present in modes the most ghastly and repulsive. The disciples of Euclid, Archimedes, and Newton might make their books a little more pleasing by a few anecdotes of these great men illustrating their discoveries, and by adding a few observations directing attention to the important uses to which their sublime problems may be applied. Elihu Burritt has written a really learned and agreeable text-book on Astronomy. Sir William Jones, in his treatise on "Bailments," has proven how interesting one of the very dryest of all the subjects of the common and statute law of England may be rendered by a writer of genius. Richerand made the study of human physiology attractive. Cuvier exhumed the fossil bones of the extinct mammalia, and robed the ancient rocks in which they were buried before "the flood" with the radiance of a resurrected world. Fortunately the classic historians and poets of ancient Greece and Rome are yet studied as text-books in our academies and colleges; and the boy who quickly forgets all that he learned with difficulty of "quadratic equations" and "conic sections" will remember forever the delightful narratives of Cæsar and Xenophon, the orations of Cicero and Demosthenes, and the lays of Virgil and Homer.

It should never be forgotten by those who write books which they intend to be read and remembered, that all minds grasp and comprehend most easily, and all memories retain most

tenaciously, whatever is most exciting and pleasing to the imagination. This must be my excuse for whatever of "the poetry of science" may appear in these brief lectures. The unpoetical mathematician would prefer the subjects embraced by them presented in the forms of skeletonized diagrams and problems bristling with algebraic signs, and geometric angles, tangents, and curves. He cannot discern the beauty, or discover the use of "the froth and foam" and the bubbles which glitter with prismatic hues upon the Mississippi's mammoth tide, and he looks with contempt upon the lilies and loti which sparkle upon the bosoms of the placid lakes, and fails to see the gorgeous and lovely profusion of foliage and flowers which wreathe and veil their banks and shores. He prefers by the four rules of the science of numbers to estimate the cubic inches of water which they contain, or the precise amount of the mud which causes their turbidity or forms their deposits. I admire the patient toil and useful taste for calculation of our practical operative mathematicians; and I am exceedingly anxious to see them engaged in the useful task of applying the hydraulic plans suggested in these lectures. They delight in making all the estimates of the cost of the materials and of the labor which their application will require in all its details, and which I have carefully omitted. My object has been to give plain and palpable outlines of plans very necessary for our welfare, the details of which any practical mathematician can supply, and which any efficient mechanic can execute without understanding the technical terms of science.

I have another benevolent object in view in presenting these important and easily applied principles of hydraulics in the simple form of lectures, precisely as I delivered them in New Orleans. If the General and State governments of our country should long procrastinate, or neglect entirely the application of proper plans for the drainage and irrigation of our public alluvial lands, and the prevention of their overflows, in many instances corporations or individuals who own such lands may improve them without the aid of either the Federal or State government, if they have the ability to utilize the directions I have given them. Although they may not be able to remove the obstructions to the navigation of the rivers which are the property of the United States, and which it is the exclusive duty of the General Government to improve, individuals have the right to prevent the inundation of their own lands, and to drain and irrigate them if they have the power and choose to exercise it.

The science of Hydraulic Engineering as applied to the control of water-currents has not kept pace with the march of this age of progress, and but few additions have been made to the text-books embracing this department of Civil Engineering which were taught in our institutions of earning thirty years ago. I am not aware that any of them written before or since 1832 teach the principles explained in these lectures which I here present as a few contributions to assist the present and future labors of hydraulic engineers. I hope that whatever is new and useful in them will find a place in the improved works which at no distant day will be prepared for students, and that they will apply it in improving the condition of our country and other lands.

If any one who reads these essays doubts whether the principles enunciated and the rules given to direct their application are nothing more than mere untried theories, I assure the skeptic that I have tested each one recommended by the most elaborate and careful experiments. Some of the most valuable discoveries were made while I was making experiments to apply practically and cheaply the principles and working plans of nature in utilizing water in motion.

IMPROVED METHODS

OF

HYDRAULIC ENGINEERING,

FOR

CONTROLLING AND UTILIZING WATER CURRENTS,

AND

ITS GENERAL APPLICATION;

Also, its specific appliance—

1st, TO DRAINAGE AND IRRIGATION;
2d, TO THE IMPROVEMENT OF LAKES AND HARBORS: AND,
3d, TO A GENERAL LEVEE SYSTEM CONNECTED WITH JETTIES, TO GIVE PERMANENCE TO BANKS AND SHORES, TO REMOVE BARS, SHOALS, AND OTHER OBSTRUCTIONS TO NAVIGATION, AND TO GIVE FIXEDNESS TO THE BEDS OF RIVERS, AND SO TO DEEPEN THEM AS TO PREVENT OVERFLOWS.

BY

EWD. FONTAINE.

INTRODUCTORY ESSAY

ADDRESSED TO THE PEOPLE OF THE CITY OF NEW ORLEANS, LA.

[The introduction and the whole of the subjects embraced in this pamphlet were delivered by invitation to the New Orleans Academy of Sciences in three leetures, November 27 and December 4 and 11, 1877.]

A PLAN FOR DRAINING THE CITY OF NEW ORLEANS, AND FOR PREVENTING ITS INUNDATION BY THE LAKES AND THE MISSISSIPPI RIVER.

The greatest obstruction to the prosperity of New Orleans is the danger to the lives and property of its citizens, caused by the inundations and epidemics which have afflicted it, and with which it is continually threatened. The great river, varying in width from a half mile to a mile in the city, flows through it in an ever-changing channel caused by its Titanic current. The average depth of this vast volume of fresh water from Baton Rouge to "the Passes" is about 100 feet, and its mean velocity is 4 miles per hour. Within the city its surface at the lowest stage of its water-level is only 5 feet above that of the Atlantic Ocean, the Gulf of Mexico, and the adjacent lakes connected with it, and which rise and fall with the oscillations of its tides and storms. During the period of its greatest floods the surface of the river is elevated about 15 feet above that of the Gulf. The extreme variation of its surface level is about 10 feet. Its velocity corresponds exactly with the volume of its water or the oscillations of its surface. During the acme of its flood it flows with the fearful speed of 5 miles per hour. When at its lowest stage, and in its most attenuated condition, its course is slackened to 3 miles per hour. Its average velocity is about 4 miles per hour.

A peculiarity of the current of the Mississippi which is too often disregarded by those who live upon its banks, and by the engineers who attempt to secure them against undermines and overflows, is the alarming fact that *it flows as swiftly at its bottom, or upon the deepest depressions of its bed, as it does upon the sides of its crumbling banks, or at its surface!* Numerous experiments made by the most competent engineers of the United States Army have demonstrated this singular fact. Immense *water-logged* trunks of trees and large masses of tenacious clay have been found by them rolling and sliding upon the bottom of the river in the channel where it is deepest, and 100 *feet below the surface of the Gulf*, propelled towards it by this gigantic current with a velocity equal to that which moves the light driftwood floating upon its waves. Sometimes the bottom current is hurled by some obstruction to the top, where it swells above the surface level and rolls away in angry eddies. It is this bottom current, acting under the pressure of the immense depth and weight of the fluid-moving-mass above it against the deep sand strata underlying the layers of clay and other materials which compose its banks, and the whole alluvial Delta, which causes all the disasters of crevasses, inundations, and the engulfing of plantations and human abodes, and which continually menaces this city with destruction. One of the most distinguished engineers and soldiers whom Louisiana has produced, General G. T. Beauregard, can testify that he found with the sounding-line two spots directly in the current at the time he was making his observations on the cross-sections of the river near the Third District Ferry, each 240 feet deep.

The cross-sections marked on Harrison's map of the city in 1846, in the Academy of Sciences, and which was used by the engineers before the civil war as the best topographical authority, demonstrate the same appalling truth in regard to the tremendous undermining and excavating force of the bottom current of the Mississippi. At the time it was making the enormous area of batture

between Tchoupitoulas street and New Levee street, it was excavating trenches on the right bank 162 feet deep, and filling up others which it had dug out under the left bank, now covered with great blocks of buildings, 182 feet deep. *The same mammoth force is now undermining a mile of the Crescent City front with the bottom current deflected against it by the diagonal projection of the peninsula of Algiers.*

I give these disagreeable facts in regard to the physical geography of the foundation of New Orleans, and the peculiarities of the current of the mammoth river, *which will certainly rearrange all of the materials which compose it, unless it shall be controlled*, in order that the absurdity may be made obvious of building superficial levees, wharves, or houses upon the margin of the surface of the water, while this deep and terrific bottom current is left unchecked to undermine and engulf all the vain works of man erected upon stratified alluvium in which no rock is found even at a depth of 630 feet! And also that the minds of those most interested may be prepared to investigate the merits of the plan proposed in this essay for guarding them against this threatened danger.

I will mention, in order to show that this danger is not imaginary, that I made a map for the Academy of Sciences while I was its secretary, and lecturer in the chair of geology, plotted from the boring of the Artesian well in Canal street, between Carondolet and Baronne, made in 1856, and superintended and accurately reported by a committee of the most competent chemists and geologists of that institution, which is, I suppose, yet among its archives, an examination of which will show that *the foundation of New Orleans rests upon no rock for at least* 630 *feet;* but that the surface of the river flows and the corner-stones of all the edifices of the city are laid above 57 strata of the most fragile and friable materials, irregularly distributed by the alternating and conflicting currents of the *ancient Mississippi* and the Gulf of Mexico, and all the upper layers to a depth of 200 feet have been rearranged by *the modern river.*

In a lecture on the Physical Geography of the Mississippi, appended to my published work "How the World was Peopled," and the notes and diagrams added, p. 330, I have shown how the present river is acting its part as "a pigmy in giant's clothes" in rearranging the deposits made by its mammoth predecessor which drained the great mediterranean sea which existed after the glacial epoch of which the large fresh-water lakes of the United States and British America are the remains, and which made the Delta of Louisiana. I have discussed this subject at greater length in a lecture delivered in Washington City to the two Houses of Congress, April 30, 1874, published in a pamphlet, on "The Peculiarities of the Physical Geography of the Mississippi River and its Delta," and the methods for removing the obstructions to the navigation of its months.

One of these recent layers was so nearly *fluid* that the Artesian auger sunk into it 11 feet by its own weight! This rested upon more solid materials, beneath which, and 330 feet below the city, was an enormous stratum of sand, full of water like that of Bladon Springs, and which rose above the surface in an Artesian stream at the rate of six gallons per minute. This great sand-layer was 140 feet thick! Underneath it were other strata of sand, clay, and mingled alluvial materials, one of them pure clay 60 feet thick. Yet all this stratified alluvium was not only *post-tertiary* but *post-glacial* in geological age, and so recent that none of the wood, shells, or other vegetable and animal matter which it contained was petrified or fossilized in any degree. At present there is no human device in operation to prevent the bottom current of the river from penetrating and removing the whole of it, and sweeping it into the Gulf with everything erected upon it.

In several lectures on the cause of the velocity of the current of the Mississippi River, and the direction of the great currents of the ocean, delivered in the New Orleans Academy of Sciences, I have, for the sake of scientific accuracy in the nomenclature of physical geography, termed those which fall from the equator towards the poles, like the Kuro Siwoo or Black Current of the Pacific, the Madagascar of the Indian, and the Patagonian and Gulf Streams of the Atlantic Oceans, *centripetal;* and those which rise from the poles to the equator, like the Labrador and Corcan from Davis's and Behring's Straits, *centrifugal.*

While the great river thus menaces the foundations of the city with "sap and mine," the combined forces of the cyclones of the centripetal ocean current called *the Gulf Stream*, and the salt waves of Lakes Pontchartrain, Maurepas, and Borgne, threaten to "carry it by assault," and sweep it from the earth with wind and water "mingling in their might."

I do not like to be "a prophet of evil," and to lacerate the sensibilities of our afflicted people with woeful *Cassandriads* or *Jeremiads;* and I would not call their attention to another enemy whose fatal attacks are more dreaded by us than engulfment by the river, or destruction by the wings of the typhoon and the waves of the lakes, if I did not at the same time present them with a remedy to secure them.

While "the Great Father of Waters" rolls through our city his fearful but yet beneficent sea of living and purifying water, dispensing health and wealth to all who will utilize his power and receive his gifts, and while he offers his services to irrigate and cleanse our city, and to pour into it the commerce and riches of all lands, threatening at the same time to scourge it if his proffered favors are spurned, on either hand lie dead lakes, bayous, lagoons, and bogs filled with stagnant and fœtid fluid, and festering with pollution. Their arms, in the form of canals, ditches, and open gutters, green with scum, and mephitic with every form of microscopic animalcule, or vegetable algæ or fungus, whose *winged-eggs* or invisible *seed-spores* ride upon the wings of the wind to spread malaria and death, penetrate every part of the city. These open elongated cesspools are the swords entering its vitals. All the filth of it enters them; and after an exposure to the face of the sun to shock all human eyes, and to offend all nostrils, its rank and mephitic odor is diffused through the air, which it makes deadly with cholera, yellow fever, and all the forms of malarial disease which compounded filth can generate in Serbonian bog or Stygian lake.

Wise men are guided by their own eyes, and follow their own noses. Our Creator has given us *noses* to guide us. Whatever offends the nose warns us to remove it or get away from it. These open gutters, sluggish canals, and stagnant ditches and slimy ponds are disgusting to the sight and sickening to the smell. Their evaporation is deadly Avernian fog. They ought to be dried up, or piped and covered under ground, to be seen and smelt no more. They are the principal sources of our epidemics.

I repeat emphatically the assertion with which I commenced this essay, that the danger to the property and lives of our citizens caused by the sudden submergences of its banks by the perpetually shifting and undermining *bottom current* of the Mississippi, the continually recurring inundations of the city by the swells of the lakes, produced by the cyclones of the Gulf of Mexico, and the epidemic fevers generated by the stagnant water and undrained pollution of its site, are the main obstacles to its growth and prosperity. Bad government has lent its aid to these destructive agencies. But no matter what beneficent civil revolutions may occur in our city and State, the ruling powers of neither can escape the reproach of negligence, parsimony, stupidity, a disregard of the public weal, and whatever else, apart from theft, robbery, and murder, constitutes *bad government*, who permit these obstacles to the prosperity of New Orleans to continue. They drive thousands from it who come to live in it. Unable to endure these nuisances and perils, they leave it with their families, and carry their capital and business to safer and more pleasant cities. They prevent the settlement of hundreds of thousands of refined and intelligent people and the investment of many millions of dollars in New Orleans. They give all the most enlightened and virtuous citizens who are compelled by circumstances to live in it an aversion to their abode. They cripple or destroy schools and churches, as well as manufactories and business establishments of all kinds. No intelligent and affectionate parents are willing to live and labor, educate their children, and plant their posterity where their eyes are perpetually haunted with hideous rills and pools of filth, and their nostrils filled by day and night with abominable smells; and where they and their offspring are liable at any time to die of some form of fever generated by foul putrescence, to be swallowed by the subterranean current of the Mississippi, or drowned by a flood from Lake Pontchartrain. Thus the fire of patriotism is quenched, and all the useful and magnificent works which only patriots perform for the utility and glory of the homes of their nativity or adoption are prevented. But few people, whether native or immigrant citizens, love New Orleans, or regard it as their permanent abode, or the future home of their posterity. The most of her residents consider it as a temporary *locum tenendum*, and a place only to be occupied while the necessity endures which compels them to brave its nuisances and dangers. They are determined to go with their families, as soon as they can, to live and die in some cleaner and less endangered city.

The plan which I propose for abating these nuisances and removing these threatening and attacking perils would effect a radical metamorphosis in the physical condition of the city, and a change as thoroughly beneficent in the sentiments, morals, character, and circumstances of its inhabitants. It would transform all the virtuous and intelligent among them into patriots blessed with health and prosperity, willing to live and labor for a home which they would love as their only cherished earthly abode, and which would be the most favored, lovely, and magnificent city beneath the sky.

Lake Pontchartrain must not be used for the drainage of the city. All bayous and canals intersecting it must be separated from this lake. While the connection between them exists all drainage plans for health and safety from overflows will be worthless and perilous.

PART I.

DRAINAGE AND IRRIGATION

BY

EKMUZESIS;

ITS GENERAL APPLICATION TO ALL MARSHY AND OVERFLOWED LANDS INTERSECTED BY RUNNING WATER, OR NEAR TO NATURAL OR ARTIFICIAL WATER-CURRENTS, WHOSE BOTTOMS ARE LOWER THAN THE BEDS OF THE SWAMPS AND SHALLOW LAKES TO BE DRAINED, AND ITS SPECIFIC APPLIANCE TO THE DRAINAGE AND WATER-SUPPLY OF THE CITY OF NEW ORLEANS AND THE SWAMP-LANDS OF LOUISIANA.

PART I.

DRAINAGE AND IRRIGATION.

I present this connected plan, consisting of three parts, as a whole system which is constructed to suit the future extension of New Orleans. Portions of each of these three parts ought to be applied immediately. The rest may be utilized as the expansion of the area of the city may demand it.

First. The drainage of the city and the malarious marshes near it, and their irrigation after their desiccation.

Second. Its protection against inundations from the lakes, and the improvement of Lake Pontchartrain for the objects of health, commerce, and pleasure.

Third. The prevention of the destruction of property by the shifting of the channel of the Mississippi River, the undermining action of its current causing the submergence of its banks with all the superficial levees and structures erected upon them, and the gaps and crevasses through which its waters at flood-tide rush in destructive torrents over the plantations of its valley.

The whole cost of the drainage of New Orleans on both sides of the river by the Bonnet Carré and Gretna aqueducts and their sewers will be less than $2,500,000, if the whole work is done honestly and faithfully.

While I ask you to fix your minds upon the whole of this hydraulic plan, which ought to be executed as *a whole*, unmutilated by any work upon either of its parts which might mar its unity, I will now present a brief elaboration of its three separate portions. I can only give, without being tedious, its distinct and intelligible outlines, leaving the details of the work to be prepared by the engineers who will have the labor and honor of its mechanical execution. After mastering these outlines and the few new principles involved, and whose application is necessary for its successful completion, each part of it will be found so simple that but little genius or talent will be necessary to enable any honest and energetic engineer to execute the whole plan.

I hope your minds will not be confused by a view of the magnitude and cost of this plan in its unity as it will appear to the imagination. Only a part of it will be constructed at the expense of the city, which is the first part on drainage within the city by two canals with aqueducts. The pipes for drainage into these aqueducts necessary now ought to be laid as soon as possible; but the most of them presented on the maps of the complete plan may be added successively, year after year, as the future growth of New Orleans may demand their use. The drainage and desiccation of the marsh and swamp lands ought to be performed at the expense of the whole State of Louisiana, because she owns these overflowed and worthless bogs, and she alone ought to pay for their improvement. All the improvements suggested and explained in the second and third parts, and which refer to Lake Pontchartrain and the Mississippi River, should be done by the Government of the United States, in which alone is vested the title of these public waterways of commerce.

THE DRAINAGE OF THE CITY OF NEW ORLEANS AND ITS ENVIRONS, AND THE IRRIGATION OF THE RECLAIMED AND DESICCATED MARSHES.

To make this complete, in view of its future extension, and to secure its health, and especially its exemption from diseases caused by local malaria, in its present condition, the drainage should include all its environs, embracing the peninsula of Algiers, and all the area lying between the Mississippi River and Lakes Maurepas, Pontchartrain, and Borgne, with their connecting waters, about 400 square miles in extent, as speedily as it can be applied. I recommend the construction of

a *canal-aqueduct without locks*, 30 feet wide, 27 feet deep, and 36 miles long, taken out of the Mississippi River at Bonnet Carré Bend, and turned into it again a short distance above the Noyes Canal near the upper curve of the English Turn; and another of the same size, and 6¼ miles long, across the neck of the peninsula of Algiers, from Gretna to a point below the English Turn, each outlet to enter the river at an angle less than 45° to the general direction. I suggest the depth of 27 feet in order that the bottom of the aqueduct may be below the beds of all the bayous, lagoons, and other stagnant waters and marsh-lands intended to be drained, and also that the mouths of the largest sewers may be covered entirely by the running water of the aqueduct. The water-level in the aqueduct must at all times be higher than the tops of the sewers in order that the suction by the attraction of cohesion of the fluid in the sewers by the larger volume of running water in the aqueducts flowing at an angle of from 11¼° to 45° in contact with their openings may be complete. The same rule must be observed where the sewerage is run into natural streams. Unless the proper angulation is observed the drainage will not be efficient. If the depth of 27 feet is not sufficient to cover the mouths of the large cylindrical sewers, the aqueducts must be made deeper, or the mouths of the sewers must be widened and flattened. The depth of the aqueducts must be measured, not from the natural surface, but from a line from the heads to the mouths drawn above the highest water-level of the river. For our present use, and for that of our successors for twenty years *probably*, these dimensions will be sufficient. In consideration of our financial depression, they may be constructed of wood, and they should not be used for any other purpose than that of drainage. They will last, and serve for that use only, and possibly be sufficient to accomplish the sanatory and other beneficial objects, for the fifth part of a century. But if before that brief period shall elapse, the growth and necessity of the city shall require it, the whole *aqueducts* will be enlarged; and others may be used for manufactories, irrigation, the supply of fire and other engines, and many other useful purposes. Various parallel aqueducts, separated from those made to convey the sewerage of the city, may be drawn from the same inexhaustible source, and conducted to the same safe and ample outlet, and confined in walls of iron, glazed pottery, or other costly and permanent materials such as the necessities of 5,000,000 of people may demand, and which their wealth and taste will enable them to construct.

With such a contingency as the necessity of future extension presented to us, in surveying the ground for our present humble work, provision should be made for the expansion which our more prosperous and powerful successors may give it. Therefore the breadth of an acre of land, or 210 feet, on each side of the canals, for the whole length of their course, should be reserved unencumbered by buildings, and unfettered by any private or other legal rights which might prevent the enlargement of the work to meet the demands of our multiplied posterity.

The modest wooden structures proposed will be amply sufficient for our present wants, and will tax sufficiently our depleted resources. Between the two points on the river selected for the inlet and outlet of the canal for the left bank in which the wooden aqueduct is to be built, the distance by the *mid-banks* channel of the serpentine course of the Mississippi is 46 miles. By the proposed canal the distance is only 36 miles. By this saving of *ten miles* the principle of the "cut-off" between bends, or greater *fall* and velocity of current, is secured. (See Plate IV, Diagrams 4, 5, and 6.) The planking with which the aqueduct is to be lined will run parallel with its course to avoid friction or any resistance to the rapid flow of the water. The bottom of the aqueduct must be dug entirely below the bottom of the Saint John Bayou, or that of the deepest tributary of the lakes which it will drain, and about eight feet below the lowest-water line of the Mississippi River, during the most attenuated stage. It must be dug its whole distance below the lowest water-level of the river, and also somewhat below the surface of the lakes, in order that there may be always in it a depth of from 8 to 15 feet of swiftly-running water. At proper intervals, about a quarter of a mile apart, spaces must be prepared and properly marked for the insertion in the sides and on a level with the bottom of the aqueduct of the main sewers. The size and number of these will depend upon the area necessary to be drained, and they can be constructed, and inserted successively as the necessity for their use shall arise. At least six of them are necessary now to drain the filth of the city and the contiguous marshes, and as many more should be constructed, to desiccate the swamps nearest to it, as its finances will permit. In order that they may perform their work well, all the pipes and sewers

must be made to enter the canals and each other at angles of from 11¼° to 45° *with the direction* of the course and current of the water. A greater angle than 45° will prevent their most efficient action. The main sewers should rest upon the bottom of the aqueduct, and their inner rims must be shaped to fit the inner surface of it; but no parts of the pipes or *sewer-ends* should fail to reach the inside surface touched by the water of the bottom current, and they should not project into it. If properly constructed the *ekmuzesis* will be complete. The bottom current of the larger body of water in the aqueduct passing rapidly by the mouths of the sewers, *by the attraction of cohesion will suck out* all the fluid they convey in contact with it. I recommend that the mouths of all these sewers be made of pottery, glazed on the inside, and crooked and shaped at the proper angle for insertion at the time they are moulded. All of their larger sections should be made of the same material.

The openings in these sections should all be *angulated on the same principle*, as we are taught by the *venous* circulation of our blood, which is the reverse of that of the *arterial*. The contraction of the heart propels the blood through the great arteries into the smaller, and diffuses it by propulsion throughout the body and into the little veins; but it is returned by them to the heart by *suction*. The little veins run into the greater at various angles, and discharge their blood into the *venæ cavæ*, or larger *sanguiducts*, which finally pour it into the right auricle of the heart. I hope this principle and this rule of *angulation* will be observed in the construction of the entire sewerage and drainage of this city, and in the course of time of the whole Delta and of all other swampy areas. The bottoms of the canals should be cut low to give all the sewers and the smaller pipes a sufficient fall, which ought to be carefully observed by the engineers who place them in position. Perpendicular tubes may be dropped into them from all necessary points and covered by grating or sieves of iron to strain the trash and drain the surface rain-water into the canals. But in the construction of all the underground sewerage the principle of the *vena cava* should be observed. This is *ekmuzesis*, and if it shall be wisely followed every particle of the noxious and offensive filth of this city will be easily and harmlessly discharged by the aqueducts into our grand *vena cava*, "the Father of Waters," which will pour it into the abyss of the great heart of our commerce—the Mexican Gulf.

Our language is already so overburdened with useless words, many of them synonyms, while the most of them are insignificant, and the whole worthless addition to our mother tongue mainly the work of shallow-minded pedants who make it year after year more difficult to be read, spoken, or understood, that an apology is due to the whole world by the man who ventures to give a new word to our cumbrous dictionary. *Ekmuzesis* is the only word I ever coined. I invented it, not because it is a thundering Greek derivative, from *ek*, out of, and *muzeo*, to suck, which in a scientific controversy, and especially in a metaphysical contest such as theological disputants sometimes wage furiously, is said to be worth a thousand arguments, but for the reason that I could find no word in our language which properly designates the application of the principle of nature by which fluids flowing in large channels, by the attraction of cohesion suck out and blend with their currents those which are brought into contact with them through smaller ducts. The phrase "*sucking out*" is rather rough and awkward, and I therefore prefer my sole coinage, and only offense to my native language, *ekmuzesis*, which expresses the idea as well; but for the use of which I beg pardon of all who read, write, or speak it.

I am afraid, while I describe the beautiful invention of *ekmuzesis*, that you may overlook the important fact that the efficiency of the plan of drainage I recommend does not depend upon the successful application of this useful scientific discovery. The whole plan of drainage was elaborated before I made it. The leading idea of the whole plan is *to drain the noxious fluids of the city and the contiguous marsh-lands into deep canals enclosing well-constructed aqueducts to prevent these cut-offs, which will be shorter and swifter than the river curving around the bends, from enlarging and making new river-beds. These deep aqueducts are to be taken out of the deep current of the river and turned again into its depths by a shorter route than the natural serpentine course of its waters; and all the mouths of the sewers intended for low marsh-drainage must descend to the level of the bottom currents of these canals, which they must be made to reach by properly graduated falls.*

In every instance the mouth of the sewer must be entirely covered by the water in the aqueduct, bayou, or river into which it enters, in order that the cohesion of the fluids and the suction of the

smaller by the larger body in motion may be complete. The larger body will always draw the smaller along with it if the discharging-pipes or sewers are angulated properly from $11\frac{1}{4}°$ to less than 45°. At less or greater angles they will work badly or not at all.

There, at their points of contact with the aqueducts, their contents must be discharged into them either by *ekmuzesis* or by some other mechanical contrivance.

It was while seeking for the simplest, the most efficient, and above all other considerations *the cheapest deviee*, that I made the discovery of *ekmuzesis*. I had studied the plans of various draining-machines and steam-pumps for transferring the contents of our vile cesspools, Augean stables, and *chartered Stygian and death-dealing canals* into a purifying aqueduct of living and life-saving water; and after revolving in my mind the *known* and many *untried windmills* and *steam-drainers*, I found them all either too expensive, or unreliable contrivances which would not work during the raging of a cyclone, when a deluge is falling from the sky, and when Pontchartrain, lashed into fury by the wings of the tempest, threatens to overwhelm the city with its waves. When we want these *tricky servants*, especially our draining-canals and draining-machines, to work the hardest and fastest to save us, the steamers stop work or desert their posts in despair, and the canals "join the enemy," and swell the forces of the invading flood. They, and all the devices hitherto used, seemed to my mind as impotent to protect us against the combined powers of the typhoons and lakes as the much-used *and mueh-abused broom* of the sage Dame Partington to sweep the swelling Atlantic from her cottage floor. I then invented a simple water-wheel to be revolved by the current of the canal, and which would work a powerful pump by night and day, and in a tempest as well as in the calmest weather—a cheap wooden contrivance, which would only require one hand to grease it and keep it in order, and which would perform its labor even without grease or any attendance, and work the hardest and fastest when the water is the highest. Six of these inexpensive machines, which consume nothing, and which are almost self-acting and self-supporting, stationed at the mouths of the main sewers, a quarter of a mile apart, to discharge their contents, are cheap enough for any reasonably economical plan of drainage; and I cordially recommend them to all those who cannot grasp a new idea and who cannot comprehend the utility of a new device until some bolder spirit uses it successfully.

Here with these water-wheels, simple as the *flutter-mills* made by little mountain boys, and placed upon the rills of their native glens, I might have closed my drainage plan. But in view of the diminished resources of our city and State I concluded to devise something even cheaper than my little "flutter-wheels"; and as you know that "necessity is the mother of invention," I can say with truth that the poverty of New Orleans, and the stern necessity for rigid economy which oppresses our whole State, is the mother of *ekmuzesis*.

IRRIGATION.

(See Plate IV, Diagram 4.)

It is easy to see how the same aqueducts constructed for drainage may be used for irrigating the bogs and marsh-lands they desiccate. The Mississippi, and the bayous leading from it, like the Atchafalaya, Lafourche, and others; and its great affluents, like the Red and Arkansas, and all the smaller tributaries, during their periods of flood have their water-levels high above the surfaces of the cultivated fields which they intersect. If these fields lie near their banks, and if their channels are prevented from shifting by jetties properly angulated to give permanency to their beds, the sewers and subsoil ditches may be conducted at proper angles directly into their deep bottom currents. I only recommend the use of aqueducts where the swamps to be drained are remote from the running rivers and bayous or where these streams are unrestrained and shift their banks, and in their unbridled condition would fill the sewer-mouths with mud or wash them away. But *superficial irrigating-ditches should be run directly above the subsoil drainers into the plats of ground* needing irrigation during the droughts of May and June, when the flood is at its height. When the water they convey from the *top currents* to the fields and gardens has irrigated them sufficiently, *through openings into the sewers* it can all be returned by *ekmuzesis* into the aqueducts; and all the expense of draining-machines may be obviated.

This plan is so simple, and will effect the drainage of all the marsh-lands of our State so cheaply, and render them so exceedingly valuable, that it is the duty of our representatives to stop their sale immediately at the low price now fixed as their value, and use the whole valuable and easily reclaimable area to pay our State debt, and at no distant day to so lease them as to provide for the expense of the State government and the support of our schools, and at the same time to exempt the people of Louisiana from all State taxation.

That this is entirely practicable is made evident by the following facts: There are 9,500 square miles of overflowed lands, nearly all of which belong to the State of Louisiana. Of this area 5,200 square miles are sea-marshes and trembling prairies overflowed by salt water during storms on the Gulf. Much of this area can be reclaimed by *ekmuzesis* where the deep river and its outlets run near it into the Gulf. The rest can only be reclaimed by the means used by the Dutch, or appliances similar to those by which that energetic nation has conquered so large a portion of Holland from the sea. But the State owns about 4,300 square miles of fresh-water, wooded swamps, easily drained. Four hundred square miles of this State land lie near this city and its immediate commercial waterways. Each acre, of the 256,000 acres, if reclaimed, would produce from one to three hogsheads of sugar. Even if the whole were sold for only $100 per acre it would yield $25,600,000, and double the amount of the State debt, which is about $12,500,000. The rest of the 3,900 square miles could certainly be leased on such terms as to exempt our people from all taxation.

Areas of these overflowed lands can be successively drained by the State and brought into the market as the necessity for raising funds to endow a system of State education, or to replenish the State treasury for any purpose whatever, may arise. An act of the legislature should be promptly passed *prohibiting their sale at present.* If it is not, as soon as capitalists discover how easily and cheaply they can be drained, individuals and land-rings will be apt to secure them; and they will be bought for purposes of speculation, and our posterity will be deprived of their incalculable benefits. Such reckless, *golden-egg-goose-ripping legislation* has characterized our State and Federal Governments since their origin. A greater wrong to our descendants could scarcely be conceived by selfish and cunning covetousness, or be perpetrated by cold-hearted stupidity and corruption combined. The only argument for its continued criminality is that these lands are worthless as they are, and that it is better to sell them to private individuals and let them be cultivated in rice, sugar, cotton, and fruit, or to be used as improved pastures for flocks and herds, than to lie idle as reed-marshes and cypress-swamps. This is not so. Much of our marsh-lands is owned by wealthy corporations and private individuals. Their successful experiments in draining them by this method, or those made by the State, will make all such lands, whether public or private, rise in value. Let speculators buy and sell their own. The State should be *in no haste* to rob the future, and to squander the inheritance of her children. But it is said that our legislators *cannot be prevented* from passing such disastrous laws. If this is true then we have reached the *nadir* of corruption, and cannot find wise and virtuous representatives to make our laws. We do not deserve to be land-owners, or *freemen;* and are too stupid and corrupt to govern ourselves, which I am unwilling yet to believe.

When I reflect how the problem of *subsistence for the multiplying millions of our race* has perplexed wise and benevolent political economists, who have not been able to devise any provision for employing and feeding the vast multitudes of India, China, and other densely-peopled countries as they will inevitably increase in the near future without the intervention of the destructive agencies of pestilence and war, and how it *is solved by this discovery,* I am overwhelmed with wonder and gratitude in view of the grandeur of the beneficent results which will flow from its certain application. The impoverished myriads of the inhabitants of the marshy valleys of the Yanktsekiang, Hoang-ho, Cambodia, Ganges, and Indus will not perish nor migrate for the want of lands to cultivate. Every untillable and uninhabitable bog and jungle can be reclaimed and transformed into the most prolific soil, to furnish abundant food for ten times the number of people who now live upon their alluvium. Every quagmire of the Danube, the Po, the Amazon, the Orinoco, and their tributaries, and all the great rivers of Africa, in the course of time will be dried and sanified by it. There is not a marshy region of the earth through which a canal of running water can be carried which will not be reclaimed

by it when the wants of a dense population shall demand it. The same aqueducts for draining and drying the marsh-lands will also be used in periods of drought for their irrigation. Ordinary ditches, leading from them when they are full of water, or simple water-wheels when their currents are below the levels of the fields, orchards, and gardens, will supply them with moisture when rain is wanted; and all the wasted water will be returned into the aqueducts by *ekmuzesis*.

This system of drainage and irrigation by the same simple contrivances will give a healthy and ample circulation of water to every river-valley independent of any supply from the clouds, and even enrich the sands of Sahara, and the great deserts of Asia and America, and all the sterile regions intersected by such rivers as the Nile, the Rio Grande, and the Colorado of the Great Basin. It will work as efficiently to nourish and cleanse the soil of our mother earth as the circulation of the blood by the arteries and veins supplies the human body with fluid, and purifies it from its stagnated and unhealthy excess. I know that we cannot fix any limit to the inventive power of the human mind, and I dare not assert that a better plan of drainage and irrigation may not be invented by some genius to whom the future may give birth, but I will say that no mode so simple, cheap, practical, and effective has yet been planned in the present era or in past ages; and I cannot conceive how it can be improved in any future period of time, unless a better plan for the circulation of the blood can be discovered than that which Eternal Wisdom has created, and of which this hydraulic system is an humble human imitation. It is but a copy of "nature's model," and the application of nature's hydraulic system—the wisest and best, because it is the work of God alone, whom it is our duty to worship and imitate.

This plan will drain every lake, swamp, or marsh intersected by an aqueduct, or by a river or running bayou whose bottom current is lower than the bed of such shallow waters and marsh-lands as need desiccation. By the same cheap and simple method all such spots may be irrigated after drainage without the aid of machinery, by surface ditches, when the water in the aqueducts or natural streams are filled by the spring rains, and flow with surface-levels above those of the lands near them. All the alluvial lands of the Mississippi, and other rivers with which I am acquainted, answer these conditions, and need these improvements. There are no cities whose plans of drainage may not be greatly improved by the proper application of these principles, and especially the *ekmuzesis* dependent upon the proper angulation of sewers and draining-pipes.

When it is necessary to drain swamps into bays like the Delaware and Chesapeake, which have tides, and which have to be utilized in consequence of the impossibility of making the culverts or sewers reach the direct onward flowing ocean currents, as represented by Diagram 3, Plate VII, the drainage must be effected by forking the outlets of them as in Diagram 4, Plate VII.

The Tiber Creek and other sewers might be made on this principle to drain the flats of Washington City into the Potomac. While the general direction of the sewer near its mouth should be at right angles to the course of the river, it should be forked into divisions each of the same size, and equal in capacity to the main sewer. They should enter the bottom currents of the river at angles of about $22\frac{1}{2}^{\circ}$, and be at all times covered by the water of the river, so as to expose the two diverged mouths alternately to the suction of the ebbing and flowing tide. When the tide is flowing up the river the mouth (*a*) will be idle, but the mouth (*b*) will receive the *ekmuzesis* of the ascending tide and pour the contents of the sewer into it. When it ebbs this upper mouth (*b*) will be calm, and the lower mouth (*a*) will be sucked by the outflow, and discharge vigorously its filthy waters into the ocean-bound river. (See Diagram 4, Plate V.)

This plan may be applied successfully to the drainage of the Kidwell flats, and all marsh-lands situated upon tide-water creeks, inlets, gulfs, and bays. But their tidal currents must be first utilized so as to give fixedness to the channel-beds and permanency to the shores by the application of the method for utilizing ebbing and flowing or tidal currents, illustrated by Diagram 9, Plate III.

The mouths of the sewers must always be covered by the water into which they discharge their contents, in order that they may receive the full force of the suction of the attraction of cohesion, and also to prevent their mephitic matter from tainting the air.

PART II.

THE PHYSICAL HISTORY AND GEOGRAPHY

OF

LAKE PONTCHARTRAIN,

AND

ITS CONNECTIONS WITH THE MISSISSIPPI RIVER AND THE GULF OF MEXICO;

WITH A PLAN FOR ITS IMPROVEMENT, INCLUDING A METHOD FOR THE CONSTRUCTION OF CHEAP AND PERMANENT BREAKWATERS FOR THE PROTECTION OF HARBORS WHOSE BEDS ARE SAND, CLAY, AND OTHER FRIABLE MATERIALS.

PART II.

THE IMPROVEMENT OF LAKE PONTCHARTRAIN.

The health and commercial prosperity of all the Delta of Louisiana, north of the Mississippi River, and below Baton Rouge, depend upon the reopening of Bayou Manchac. The deepening of the two entrances to the Gulf, Chef Menteur and the Rigolets, and a lake harbor, all deep enough to admit ocean vessels of a large draught through the Mississippi Sound to New Orleans and to Baton Rouge, can only be effected by the improvements planned in this essay for this bayou and Lakes Maurepas and Pontchartrain. The overflows of the lower coast and of the whole Delta will be prevented if a proper system of levees, protected by angulated jetties connected with them, is applied—the jetties always to be constructed above the caving banks to deflect the bottom current of the river from them, and to deposit batture against them. Without these improvements for this bayou and these lakes and their outlets, no plan for the sanatory and commercial welfare of New Orleans will be complete. The cost of the whole plan will be less than $1,000,000.

This beautiful lake, although it lies within the limits of the State of Louisiana, is, I suppose, the property of the United States by the same title which gives it the ownership of the Mississippi River. The cession of Louisiana to the United States by France conveyed with it this great river and all its navigable tributaries, and the lakes connected with it and the Gulf of Mexico, which are waterways of commerce. These "public highways" and commercial avenues, in which all the people of the United States are interested, have never been relinquished by the General Government to this State. As the ownership of this lake and its connections with the great river and the sea is vested in the United States, it is the duty of its Congress, for the "general welfare" of the people, to make all the improvements which the necessities of commerce and other objects of public utility require. National justice demands that this should be done for this river and lake, and for all the avenues of travel and traffic leading to New Orleans, with the same liberality and for the same objects as appropriations of the public money have been made for the improvement of the harbors of Boston and New York. Even if the city of New Orleans or the State of Louisiana were in a condition to undertake the work of hydraulic engineering necessary to be applied, and which our highest interests so urgently demand, the consent of the Government of the United States through an act of Congress would have to be obtained. Even in the application of the plan of drainage which I have recommended, and which the health and commercial prosperity of New Orleans require the city to execute immediately, such an act of Congress may have to be obtained. To make the drainage of it effective, the Bayou Saint John and the canals and basins of stagnant water should be drained.

I have been informed by some of our most eminent lawyers that the right of property in the Bayou Saint John is clearly vested in the United States. At the period of the purchase of Louisiana from France this bayou was an important commercial waterway; and when New Orleans was a fortified village it was considered indispensable to its prosperity, but now that it has grown to be a great city, it has become a nuisance and an offensive generator of malaria. If an act of Congress is necessary it ought to be obtained immediately, in order that this stinking cesspool may be drained and dried as soon as possible, and its bed transformed into streets and lots for buildings and gardens. All the other receptacles of filth and putrid water, the canals and basins within the city and its environs, ought to be destroyed and their commerce transferred to the shore of the lake and to the lines of railroads terminating at its wharves. The city authorities should lose no

time in abating these nuisances, which are the principal causes of our epidemics and malarial diseases, and, as such, the main hindrances to the growth and prosperity of this metropolis. If our representatives in Congress will do their duty, it will not be impossible, or even difficult, to get the General Government, of which as the representatives of the people of Louisiana they form a part, to make all the appropriations of money necessary to improve Lake Pontchartrain and its necessary connections with the Mississippi River and the Gulf. It is certainly the duty of the United States to do this.

THE IMPROVEMENT OF LAKE PONTCHARTRAIN.

In 1814 this lake received a very large supply of fresh water directly from the Mississippi River through the Bayou Manchac. This bayou left the river opposite *Manchac Point*, about 12 miles below Baton Rouge, and after coursing along near the high and beautiful hills which are the escarpments of the fertile alluvial "bluff-formation," upon the plateau of which are built Natchez, Vicksburg, Memphis, and other fine cities, it discharged its muddy waters into Lake Maurepas, distant from its head on the Mississippi on an air-line about 32 miles. But it reached its mouth in this lovely lake after meandering at least a hundred miles through recently formed alluvial lands of inexhaustible fertility, and near the more elevated plateau of the bluff-formation crowned with grand primeval forests of beech, magnolia, and all the finest trees of the southern woods, and dotted with the multiplying settlements of thrifty planters. On its course it received the waters of the pure and bold Amite, which rises in the pine forests growing upon the barren sands and pebbles of the glacial drift which supports all the vast pitch or long-leafed pine woods of the South, which peculiar soil of variable depth overlies all the lower surface-depressions of the tertiary, and furnishes the exclusive food of this valuable tree, which does not grow indigenously upon the tertiary, or any older formation which "crops out" through this diluvial "orange sand" deposit. This water-worn and discolored detritus of the post-tertiary glacial flood which poured over North America from the Arctic Ocean is widely strown over all the Gulf States, and covers all the upland areas of Mississippi, Louisiana, Alabama, and parts of Texas, Arkansas, West Tennessee, and Florida, no matter what may be the denuded formations lying immediately beneath it. But it is the *general surface* of the tertiary formation of the Gulf States, and the only land upon which the forests of the long-leafed pine are found. The Amite and its numerous tributaries flow out of these pine lands and through the far more fertile bluff-formation upon which no long-leafed or other pine grows spontaneously. This is a recent deposit which *overlies* the glacial drift. It was formed by a local deluge or the drainage of one of those post-glacial seas, such as existed upon all the continents, and were drained in a subsequent epoch, and either synchronously or successively in times not very distant from our present era. The particular fresh-water sea, whose drainage formed the Delta of Louisiana and much of the flat coast-lands of Texas, and all the bluff-formation of the States of the valley south of the Ohio River, existed between the Rocky Mountains and the Appalachian chains, and the older connected and denuded sedimentary rocks of the Ozark and Cumberland, which before their disruption and severance formed the southern shore of this mediterranean sea, whose northern limits, penetrated by the McKenzie and other Arctic rivers, have not been explored. It was certainly drained by the Mississippi River, which, after tumbling for ages over a great water-fall above Cairo, whose marks are seen upon the lofty cliffs on both banks, cut its way up towards the upper part of the rim of this great sea by a process of erosion similar to that by which the Niagara is trenching its chasm towards the depths of Lake Erie at Buffalo, where its falls will inevitably disappear, and with them Lake Erie will also vanish and destroy Lake Ontario, and transform the Gulf of Saint Lawrence into a delta, and exhibit all the phenomena on a smaller scale displayed in the Mississippi Valley when the great sea, whose remains are the lakes Superior and others left in the deepest depressions of its bed, poured its waters and their wrecks into the Gulf of Mexico at Baton Rouge, and formed the vast area of the coast-lands and swamps of Louisiana, and the high plateau of alluvial bluffs, crowned with rich plantations and magnolia forests.

But this digression is more suitable to a geological dissertation than to an essay on hydraulic engineering for the improvement of Lake Pontchartrain. I would not have made it if it were not

written to be read by members of Academies of Sciences, as well as by illiterate engineers and politicians. I will say no more in regard to the physical geography of this lake and its principal affluents through Lake Maurepas, except that *these lakes and Bayou Manchac are the shrunken remains of the most eastern and northern mouth of the many mouths* of this mediterranean-sea river when it flowed in the zenith of its grandeur, and entered the Gulf from the Sabine to Pearl River by hundreds of embouchures, some of them wide as Vermillion and Barrataria Bays, and the whole volume of fresh but angry water, a hundred miles wide and 600 feet deep, rushing from Cairo to the sea, presented the appalling spectacle of a river compared with whose gigantic size and strength the magnificent Amazon in the periods of its grandest floods is but a pigmy rivulet. In 1814, ages after the drainage of this sea had been effected through these great mouths, and such climatic changes had occurred that the mammoths and many of their pachydermatous associates died, the Mississippi pined and withered away, until it could no longer fill its great southern mouths, and preserve the vast delta it had thrust into the Gulf a hundred miles beyond the present shore of Louisiana. It at length became too feeble to force its way into the Vermillion, and the other mouths it had made in the days of its manhood's prime when it filled up the whole alluvial area with logs, brush, sand, and mud, and all the materials of the lands its deluge had engulfed from the mediterranean sea to the ocean. It could not flow in its feebleness through these wood-bound barriers which it had buried, in the plenitude of its strength, several hundred feet deep. It was compelled to leave its direct southern course from the pole to the equator, at Baton Rouge, and flow through its northeastern mouths carved through the yielding *tertiary* sands and marly clays. Only a few little remnants of its ancient channels, much obstructed by logs and buried wrecks of all kinds, were occupied by the Atchafalaya and smaller bayous leading from its right bank to the remnants of its mouths in the Gulf, where all its delta has long been abandoned to the erosive action of the tropical Gulf-Stream current, which has swept away more than half of its original formation, and lowered the Mississippi to its present level.

It is now faintly and vainly struggling to extend its alluvium far out of its normal direction to the east. In 1814 Bayou Manchac was the sole representative of its ancient northeastern outlet. It was then and is now a very necessary carrier for the products of the fertile "bluff" plantations at whose base it flows, receiving the Amite which intersects the prolific plateau; and it is also much needed for the commerce of the rich alluvial lands which for a hundred miles line its banks. When General Jackson came from Tennessee, in December, 1814, to defend New Orleans against the formidable force sent by Great Britain to capture it, and to conquer and hold with it the whole valley of the Mississippi to connect it with her West Indian and Canadian possessions, he found Bayou Manchac a deep and broad navigable stream, which the British had thoroughly sounded, and through which they had determined to pass gunboats drawing from 7 to 12 feet water, to cut off his supplies from Kentucky and Tennessee, and attack him in the rear, and closely besiege him, encircled in the city by their naval and land forces without the possibility of his relief. This wonderful man had never heard anything about *jetties*, *mattresses*, or *caissons*. I doubt whether he understood the definition of a dozen technical terms of military or civil engineering, and I am sure that he knew nothing that any books could have taught of hydraulics. Such things had not penetrated the pine woods of the Carolinas, nor the wild woods and canebrakes of Tennessee and the Creek Nation, where he had spent his life before he came to defend this recently-formed *semi-aquatic spot of earth* against the most thoroughly educated and the bravest and best disciplined troops in the Old World, and who had just conquered the Old World's conqueror. He had read no books on hydraulic engineering. He needed no information which they could give him. He had seen axes fell trees, and he had seen the beavers cut them down with their teeth, and make dams with them which would guide the course of rivers, or obstruct their channels entirely with scientific works which no floods could remove. He had the divine gift of genius, and the rare but invaluable talent of common sense, and with the faculty to learn from observation and experience, and guided by the unerring instinct of the beavers, the perfect hydraulic engineers of the God of nature, he blockaded Bayou Manchac with trees and *beaver brush-work* so effectually that he rendered it useless to the British, and, unfortunately, to the planters and merchants also. In fact he almost obliterated that mouth of the old Mississippi from the face of the earth. By his original feat of hydraulic engineering he rendered abortive the British naval victory on the lake, and he saved New Orleans; but the effect of his successful work has been for sixty-

three years most injurious to the commeree and health of the residents near the bayou and its tributaries, and around the shores of Lakes Maurepas and Pontchartrain, and it has been very detrimental to the city of New Orleans.

Before General Jackson closed it, a large volume of fresh running water was discharged by it into Lake Pontchartrain. This had been thoroughly clarified by its passage through Lake Maurepas. After winding around Jones's Island it flowed into Lake Pontchartrain at the Choctaw Village by a single mouth. The volume of pure water from it so filled the lake that it gave it a strong current toward the east along its shores, quickening the currents of the Tangipahoa and Tchefunctee Rivers, and of the navigable Bayons Lacombe, Vincent, Saint John, and all the smaller streams emptying into it; and at the same time, while adding to the health of its shores by improving their natural drainage, it deepened the outlets of the lake to the Gulf through the passes Chef Menteur and the Rigolets.

The first improvement I would suggest for Lake Pontchartrain is, to *reopen Bayou Manchac*, and to utilize it for irrigation, drainage, navigation, and all the beneficent uses to which running water can be applied. As it was closed by the United States, whose power was skillfully but arbitrarily wielded by the greatest of its generals, the damage of more than half of a century, and which it is difficult to estimate, ought to be promptly and liberally repaired at its cost.

The next improvement I recommend is *to utilize the Bonnet Carré crevasse.*

The cause of the *opening of this crevasse was the closing of the Bayou Manchac.* Whenever a natural outlet for the relief of the flood water of the Mississippi is closed, the overburdened volume will relieve itself by a crevasse which it will burst through some weak point in its natural or artificial banks. It generally selects some caving bend the nearest to the outlet or mouth of the channel which has been rashly closed in opposition to the law of its natural hydraulic system, and which the wisdom of the ancient aboriginal mound-builders and agriculturists of its valley taught them to regard with sacred veneration. Instead of closing *these safety-valves for the escape of the flood-waters*, in order to save themselves from inundation, as some thoughtless engineers advise us to do in regard to the Atchafalaya, Lafourche, Plaquemines, Yazoo Pass, and others, they carefully opened them all, as did the ancient Egyptians to control and utilize the floods of the Nile. Acting upon the hints which bountiful Nature had given them, and guided by its wise and beneficent directions, they not only enlarged, deepened, guided, and carefully leveed all these natural outlets, but constructed many others for the various useful purposes of navigation, drainage, and irrigation. No physical geographer with ordinary capacity for observation can doubt this who will carefully examine the vast net-work of bayous connecting the Mississippi and the Yazoo, and see the powerful levees they built yet standing covered with the tumuli and all the remains of the extinct millions of this enlightened but vanished race, abundant as those which were constructed by the subjects of the ancient Pharaohs, and which gave to the Yazoo Ok-Hinna, its Indian name, which in the languages of the Choctaws and Chickasaws means "the River of Ruins."

The connections of the White, Saint Francis, Washita, and Red Rivers with the great River and the Gulf all prove the same instructive theory to be correct. The Nile was once an unbridled and shifting river, which, from the cataract of Syene to its mouths in the Mediterranean Sea, flowed through swamps, natural bayous, and lakes, and overflowed them all, until Menes and other wise monarchs bridled and controlled its waters with canals, aqueducts, and leveed lakes, natural and artificial, in the manner described by Herodotus. All these were used for three purposes—the prevention of overflows, drainage and irrigation, and navigation. When the Nile was dangerously full, and the land was threatened by it with a flood, after impressive ceremonies, some of which are yet observed and conducted by the modern rulers of Egypt, the water-gates at the head of each canal were opened, and the fields were all irrigated, and the dangerous water was made propitious to the soil, and then permitted to flow by many outlets to the sea. Lake Mœris, 30 miles long and 6 miles wide, leveed and guarded by water-gates placed upon all the inlets and outlets of the great aqueducts connecting it with the Nile and the sea, was filled. When the flood had spent its force, and the work of irrigation was accomplished, the gates were closed, and the water of this and all the other lakes and artificial reservoirs was retained and held at a level high above that of the valley fields, to furnish any deficiency of water for irrigation the next year, if the annual rise of the river was not sufficient to supply the wants of agriculture.

I therefore object to the theory of closing the bayous, for these unanswerable reasons: First, they are necessary for the inland commerce of the valley, because they furnish the cheaper means of transportation; second, they afford the best and only means for draining and desiccating, and then for irrigating all of its swamp-lands remote from the Mississippi; third and finally, they may be made to save the valley from overflow, as the opening of the Bonnet Carré and other crevasses and the bursting of the levees of the upper coast saved New Orleans from the May flood of 1874. Our true policy is to jetty the main river with converging brush and crib work to give fixedness to its channel and deepen it by erosion, and to open every outlet and utilize it for commerce and agriculture.

Instead of closing Bonnet Carré crevasse, I think a ship-canal ought to be made of it about 8 miles long and 200 feet wide, with a depth of 6 feet below the lowest water-level of the Mississippi, and it should be run upon an air-line due north into the southern margin of Lake Maurepas. It should be properly shielded and guided with jetties at its outlet from the Mississippi to prevent it from enlarging its channel, and also at its entrance into the lake to hinder the formation of a bar. This canal can be used for navigation and the drainage and subsequent irrigation of 64 square miles of marsh-lands adjacent to it, now worthless for agriculture, but which it will make equal in fertility and value to any in the State. The large accession of water which this Bonnet Carré Canal and the reopened Bayou Manchac will give to Maurepas will make a strong current in this lake to the east and through the Jones's Island Pass into Lake Pontchartrain, and through it into the Gulf. The current will be a continuation of that of Bayou Manchac, which, although it will be swift and deep, will be easily controlled by jetties of piles and fascines of felted brush. There will be but little current in the canal, as there would be if its course were south or even east, and it will need no lock.

Many years ago I discovered, and ten years since I demonstrated in a lecture to the New Orleans Academy of Sciences, that the cause of the velocity of the current of the Mississippi was not its *fall*, but its *course from north to south;* or *the centrifugal force which it receives from the earth's revolution upon its axis;* and which force propels all fluids upon its surface from the poles towards the equator, and retards their centripetal flow from the equator towards the poles. It is this force which makes the earth an oblate spheroid instead of a sphere. It causes its equatorial diameter to be about 27 miles longer than the polar. It elevates the tropical oceans under the equator 13½ miles above a globe level. It causes the cold centrifugal ocean currents to flow out from the poles towards the equator, *side by side* in the temperate zones, but opposite to the Gulf Stream, the Kuro Siwo, and other centrifugal currents which rise in the torrid zone above them, and seek their level by running to the poles, where they are metamorphosed and merged with them by the cold of the frigid zones. This force, which *retards* the currents of the La Plata and the Nile, whose course is directly *opposite to that of the Mississippi*, and which flow *from the equator towards the poles*, will act directly *against the current* of the Bonnet Carré Canal, and give it a gentle descent into Lake Maurepas.

The third improvement I recommend for Lake Pontchartrain is *a jetty of piles and felted fascines at the mouth of the pass at the Choctow Village.* This should be shaped like a V, with the point meeting and dividing the combined waters of Lake Maurepas, and directing their currents around the shores of Lake Pontchartrain to its two passes into the Gulf. The effect will be to form a large, beautiful, and perfectly healthy island at the upper end of the lake, upon which a *star-fort* can be erected to guard this important inlet. Hotels, hospitals, and buildings of all kinds can be built upon its healthy and airy site. It will enlarge its area slowly and continually, while the currents eddy around it, and deepen near the shores. These currents should be utilized for harbors a half mile wide, made by breakwaters of piles and brush fascines a half mile from the lake shore and parallel with it. The materials dredged to deepen them next to the shore, for the convenience of wharves and the motions of vessels of all kinds, should be used to construct a high and broad levee to protect the city and plantations from the storms of the lake. Intervals at least 200 feet wide ought to be left in the construction of the breakwater, at distances of two miles, for the passage of vessels. This breakwater, harbor, and levee may be extended as the growth of the city or of several cities and multiplying villas and plantations may require, until the improvements embrace and encircle the entire lake and all its connections with other waters. This with the aqueducts and canals will encompass New Orleans with a sanatory cordon of pure running water, which will shield

it against the ingress of all malaria generated *outside* of its limits. Malaria, like the mythical witch of Scotland which chased Tam O'Shanter from Kirk Alloway to the Doon, *cannot cross running water*. Residences upon islands surrounded by river or ocean currents, if their sites are kept clean from local filth, are usually very healthy. The use of drainage is to prevent the origin of local or indigenous malaria. The *yellow-fever* poison is probably a *tropical plant*, of the *fungus family*, to which the *mushroom*, *lichen*, *alga*, and all the *moulds* belong. This exogenous and imported poison will spread wherever there is heat and moisture to nourish it, and it can only be excluded by rigid quarantine. It originates in tropical filth, but, like the small-pox or itch, whether it is a minute *aterous* or wingless insect, or the spore of a microscopic fungus or other cryptogamous plant, nourished first in some filthy hovel of the torrid zone, it will poison the cleanly inhabitants of all cities of the temperate zones at a less elevation than 1,000 feet above the sea.

The first beautiful effect of the application of this plan will be seen when the breakwater is constructed a half mile in front of the termini of the Lake-end and Pontchartrain Railroads. The cyclones will dash the storm-waves against them, and roll them through the gateways of the ships and scour out the passages; but they will disperse their force harmlessly in the wide and quiet harbor, and never strike the shore; while they will transform the breakwater into a long line of islands made by the sand and shells thrown up by the tempests, and which will bury the piles and fascines out of sight. But the materials of which they are formed, and especially the willow, cypress, and other trees of the swamps, will grow and form a lovely display of living green. In the course of a few years these islands will make smooth and broad sand-beaches towards the center of the lake, and form crescents of semi-tropical lands parallel with the entire encircling harbor and shore, more beautiful than the lovely ring-shaped atolls of the Pacific Ocean. They will be crowned with bath-houses, hotels, and residences of merchant princes and planters, displaying all the varieties of convenient, chaste, and gorgeous architecture, and ornamented with all the fruits and flowers which will grow in our almost winterless clime. The glories of Chalco, Tezcuco, Como, and Maggiore will be eclipsed by the variegated pictures of elysian loveliness and magnificence which the future will display upon the bosom and around the shores of Lake Pontchartrain if this plan for its improvement shall be adopted and faithfully applied. The commerce of a city greater than ancient Rome will float upon its surface, and the millions of its inhabitants will find healthy and profitable employment, while they will be refreshed and invigorated by its purifying waves and balmy gales.

PART III.

AN EXPLANATION OF THE PRINCIPLES UPON WHICH THE PLAN FOR THE CONTROL AND UTILIZATION OF WATER-CURRENTS IS BASED,

AND ITS APPLICATION TO

THE MISSISSIPPI RIVER,

CONNECTED WITH A

GENERAL LEVEE SYSTEM.

A GENERAL PLAN FOR THE IMPROVEMENT OF ALL RIVERS AND HARBORS BY THE PROPER GUIDANCE OF MARINE AND FLUVIATILE CURRENTS TO ERODE CHANNELS, TO FORM NEW LAND, AND PREVENT INUNDATIONS.

INTRODUCTORY.

Unfortunately all attempts made and levee systems applied to control the Mississippi have been superficial. They have no reference to *the bottom current.* If that is neglected levees cannot be protected, and crevasses by undermine cannot be prevented. The channel of the Mississippi can only be deepened, bars can only be removed, levees can only be guarded, and overflows can only be averted by controlling and guiding properly this bottom current; and that cannot possibly be done by any other mode than by jetties constructed upon the plan recommended in the following essay.

The levee system properly applied to the whole river from New Orleans to Saint Louis, provided that the jetties recommended are applied to the lowest bar first, and then successively to each of the others above, and also above the concavity of each bend of the river, and connected with the top of the levee and the bottom of the river, will cost less than $10,000,000.

THE OUTLINES OF A PLAN

FOR

Controlling the Mississippi River so as, first, to guide its current and protect levees; second, to save its banks from undermines; third, to make batture, or alluvial deposits where they are needed; fourth, to remove its bars without dredging; and fifth, so to deepen its channel by erosion as ultimately to prevent overflows.

The main objects of the plan are to give permanence to its banks, and to prevent the shifting of its bed; to preserve its islands and its shores with all the property upon them, and at the same time to make it navigable, at the lowest stage of its water, to ocean vessels of the largest size.

This plan was elaborated many years since, presented to the New Orleans Academy of Sciences in 1866, approved and adopted by it January 8, 1868, and sent to the various Academies of Sciences of America and Europe during that year.

This plan has been very generally approved, but the most useful principles of hydraulic engineering embraced in it, especially the proper *angulation* of the jetties with reference to *the artificial current-channel* intended to be formed by their guidance of the *natural current*, has never so far been applied either in America, Europe, or elsewhere.

The plan is based on these two principles—

1. The *angle of reflection* of water in motion is equal to *the angle of incidence* minus the resistance. (See Plate I, Diagram 1.)

2. The walls of all jetties for controlling water, where their foundations are mud, sand, and other friable materials, or where they do not rest upon rock, or *undisintegrable materials*, must be made of brush, *latticed-diagonalized-cribwork*, or other non-reflecting substances; or so faced with such materials as to break and dissipate the force of the currents they are intended to control by hurling the particles of water which compose them against each other, and preventing their downward reflection, and consequent undermining action. None of the surfaces of the materials should be smooth, but grossed, or corrugated. A simpler and more comprehensive description of these controlling or guiding jetties may be given as follows: *They are properly angulated reflecting walls faced with non-reflecting materials.* Wherever it is applied it should control the bottom currents.

I.—THE MATERIALS FOR THEIR CONSTRUCTION, AND THEIR FORMS.

(See Plate III, Diagram 1.)

These may be varied to suit the localities intended to be improved and the depth of the water in which they are to be used; but none should present plain surfaces.

1. To control currents too deep for their beds to be reached by piles, and where it is desirable to guide the bottom currents, especially those of the Mississippi, at depths of from 40 to 180 feet, or at a greater distance below the surface, they should be made of strong cubical-formed diagonally-latticed caissons filled with loose stones, of convenient size for handling, and for being anchored, and linked together in a row or in rows upon the beds of the deep bottom currents; or they should be made of *felted fascines* strongly bound and heavily ballasted to resist the first shock of water-logged stumps, trees, and bowlders of clay, or other heavy substances hurled against them by the bottom current, and which may remove them from their alignment and connection with the portions of the jetties in the shallow water, constructed of piles and fascines, and of which these heavy cribbed caissons are intended to be the *termini* in deep water. (See Plate III, Diagrams 10, 11, and 12.) The diving-bell should be used, to see that they are compactly adjusted on the deep bottom to form an obstruction to catch and compact the silt and deflect the current.

2. For all shallow water in our soft-bottomed rivers, and the mud and sand bedded lakes, bays, and estuaries, the jetties ought to be made of piles and brush fascines—materials which grow in every swamp and bottom-land forest. The cypress, tupelo gum, swamp ash, and other watery growths, and the tall young willow and cottonwood saplings, which form the winter "towheads" of the recently-formed areas of batture, and line the margins of all the bayou and river banks, invite their use. No rock is needed for the construction of these *shallow-water jetties*. They should be made as follows:

Two rows of piles 12 feet apart, the piles in each row 8 feet distant from each other. Each pile to be made of a stout tree with *the bark to be left upon it*, and the rougher and more corrugated the better it will answer the purpose as a non-reflector in resisting the undermining action of water. The pile should be properly notched at the *lap* or *upper* end to receive the attachment of one or two *girders* or connecting poles, and sharpened at the *butt* or root end into a *triangular* or *quadrangular* point to be driven easily and to a sufficient depth with the *butt downward* (see Plate III, Diagrams from 1 to 7), in order that it may stand firmly when the currents make deposits around its base. It will then be placed on the principle of the obelisk and in the natural position of the tree. The fascines should be made of bushes as straight as possible, 15 feet long, and each one should be fastened with two *wraps* around four stout sticks radiated at right angles to the saplings or switches of the fascine of which these two circles of radiated sticks form the frame. Each stick should be barbed at one end and sharpened at both ends. It should be cut below a stout limb at least an inch thick, and this limb should be shaped by the hatchet into a barb. The points of these sticks should project at least a foot beyond the sides of the fascine. The wraps should be far enough apart to prevent any hindrance to convenient carriage upon the shoulder, and their dimensions should not be too great for the strength of an ordinary man to handle them. They must be 15 feet long in order to project at least 18 inches beyond the lateral lines of the rows of piles, between which they should be packed in alternate floors or layers at right angles to each other, and then rammed and felted together with a heavy and properly constructed *brush-packer*. (See Plate IV, Diagrams from 7 to 11.) The object of the barbed wraps is to make them hold to the bottom when driven down upon it, and to fasten *like felt* to each other when packed together, and to obviate the use of stone to weight them down.

After the space between the piles is thoroughly filled, the whole work should be girded together by 15 and 24 feet willow poles spiked into the notches mortised near the top of the piles; the 15-foot poles crossing the line of the breakwater or jetty at right angles, and the poles 24 feet long crossing these 15-foot poles and each other diagonally on the central line of the top.

These breakwaters will resist the storms of the Gulf, and form the *nuclei* of islands and sand-spits. They are buried in mud and sand, and will grow where they are planted and display living lines of willows and cypress, and the usual growth of our marsh-lands. I recommend these structures as the strongest, cheapest, and most permanent breakwaters and jetties for all our southern sea and river hydraulic defences. Nothing will be found superior to them for stopping crevasses. I suppose that the work will be faithfully executed, and its character may be greatly varied. I only recommend it for water less than 40 feet deep. They are not only cheaper than iron, but more durable.

II.—THE LOCATION AND PROPER ANGULATION OF JETTIES.

1. No jetties intended to control water-currents, to deepen, and at the same time to make permanent channels, of regular forms, and without the aid of dredging, ought ever to be made *parallel*, for these reasons (see Plate I, Diagram 5):

1. Although parallel jetties may be made to guide and to confine a current, they will not *accumulate* or *double* its erosive force by reflection from each wall, or from both jetties upon a given line, so as to form a channel of a regular and uniform shape and depth. The globular particles of water between parallels move along *parallel lines* until they strike some obstruction to their motion which will deflect them upward, downward, or laterally at angles given by its shape. A sunken ship in the channel or a rounded stone or mud-lump will part the current and hurl it with dangerous undermining force against both jetties. At the months of rivers, and especially at the passes of the

Mississippi, into which vessels entering meet those which are departing, they often collide and sink. The prow of the sunken vessel points up stream while the stern is turned seaward by the current. The currents parted by its prow are deflected with erosive force against the jetties and cut deep troughs. The eddies whirl behind the stern and meet and mingle, forming obstructing lumps, bars, or islands. Clusters of trees tied together with vines, drifting seaward, and anchored by their limbs or roots, or huge bubbles of clay lifted by vast volumes of gas generated by hammocks of logs, brush, leaves, and other vegetable matter buried deeply in the strata of the ancient Delta, produce similar effects. A large water-logged tree-trunk three or four feet in diameter, or a ship sunk near one jetty and lodged angularly to the current, will deflect its whole force against the other, which in turn will be reflected diagonally in a contrary direction, and give it a *zigzag course from wall to wall* for a distance of many hundred yards, or miles, proportioned to its velocity and the angle of the deflecting obstruction. Then the obstruction can only be removed by blasting dredging, or other mechanical force; and the channel can only be straightened and deepened by the scraping or spading of the pump, dredge, or other expensive artificial contrivance. The cross-sections of soundings below such obstructions across the parallel-jettied channel exhibit irregular curves of various kinds, and reveal a trough, shaped very awkwardly, difficult and dangerous for navigation. These facts are so obvious as to make unnecessary even these simple diagrams for their illustration. (Plate I, Diagram 5.)

Properly converged jetties reflect the water at angles corresponding with their angulation. They converge the water and accumulate it into an erosive current *continually acting* with a corkscrew, drilling, and boring motion, cutting, with the combined power of the auger and sand-blast, upon a fixed line as permanent as their position. This current, always moving upon a friable bottom of mud, sand, tenacious clay, or even disintegrable chalk or sandstone, will bury in it or remove from it any object whatever. It will cut away mud-lumps and islands, float off any wooden or other bnoyant obstacle, and by excavating the fragile bottom, guided downward by the reflecting sides of an iron ship or block of stone, it will bury the solid and heavy obstruction and shape the bottom of the channel in a form corresponding with every other part of the trough excavated by the guidance of the angulated and converged jetties. (See Plate I, Diagram 4.)

2. Parallel jetties cast no accumulated erosive current beyond their points. The water which runs through them is immediately diffused and spreads out in all directions. They are as unscientific as cylindrical tubes attached to the ends of the hose of fire-engines for throwing water. *They scatter well, but will not squirt far.* Pipes like *inverted cones, sections of which are the lines of converging jetties*, propel the water much farther with concentrated erosive force, and will form an eroding current which will remove obstacles far distant beyond their extreme points. (See Plate V, Fig. 1.) Within the banks of rivers batture will always form between their points and the banks, and against the banks along their curving bends at distances below their points proportioned to their angulation and the velocity of the current. At sea, upon shallows where it is necessary to connect their angles throughout their extension to guard them against the ordinary currents and the more violent action of those produced by storm-winds, which would break through them if they were disconnected, cut trenches across the artificial channel, and fill it with sand on either side of the gaps; if they are properly constructed the batture will fill up only the angles and leave a trough open with its sides parallel and aligned with their points, while vast areas of land will be formed on each side of them from their points to the mainland.

II. *Jetties should never be located at right angles to the current, or to the line of the bank of the river they are intended to protect*, for these reasons:

1. Although such jetties *confine* a river or sea current and give it a greater depth, they do not *guide it* either above or below their points. The central current flows directly on at right angles to their lines. The left and right flanks of it strike the jetties perpendicularly. Their under currents checked are thrown up and down, and excavate their foundations if they are smooth; or if they are latticed, corrugated, or made by other means non-reflecting, they accumulate deposits against them, and spread out laterally. One portion acts directly against the whole volume of the central current which whirls it against the bank below the jetty and excavates at the same time the bottom below the foundation of the jetty-point, and the other portion above is thrown directly against the bank and undermines it, and destroys the connection of the jetty with it. Unless addi-

tional works are constructed giving the fastening of the rectangular jetty to the bank the form of the letter T, a portion of the river will cut off its connection with the bank, pass through the gap, and form an island of which the jetty will be the nucleus or frame-work, and one of its diameters. This reveals two other objections to this angulation of jetties already stated.

2. The rectangular jetty, requiring one or more extensions L or T at its base or connection with the shore is too expensive; and if these additional works are not constructed to secure the land from *undermine* and submergence it will make *crevasses* and swamps; and it is,

3. *Dangerous* as well as *worthless.*

I have heard these arguments urged in favor of this plan of rectangular jetties:

1. The rectangular jetty is less expensive than the diagonal, or the deflector, or converger, which are different names for the same thing, because it is one of the *short* lines of a right-angle triangle, while the *diagonal* is its *longest line*, or the *hypothenuse.*

To this I answer that *the entire hypothenuse* of the rectangular triangle need never be used on the Mississippi River or elsewhere to protect the banks, to make batture, to remove bars, or to deepen channels by removing other obstructions. *Only a part of this line properly angulated* is necessary for the construction of the jetty. Its length will be proportioned to the width of the river and the depth of the water, and the distance of the bottom current from the bank. Where the river is the widest the jetties should be the longest; but in such places the current is the weakest and the water the shallowest, and consequently the jetties may be made in the least expensive manner, and they will cost less than short jetties in deep water flowing with swift and strong currents, and which will require heavy and expensive mattresses or caissons for their construction, while these long jetties, to confine and guide the water to make it erode deep channels across bars and shoals, can be built of cheap piles and felted fascines without the additional expense of stone or iron, so as to be as strong and durable as the most permanent works of man. (See Plate IV, Diagram 3.)

2. It has been said in favor of rectangular and parallel jetties that Sir Charles Hartley removed with them the bar at the mouth of the Danube. This is a mistake, as will appear from the following diagram of his work. After a survey of the Danubian mouths in 1829 various efforts were made for deepening the bar of the Sulina mouth, which was deemed the most practicable, and which had a natural depth of 10 feet. The useful idea occurred to the engineers as early as 1857, that if the water could be confined to the ordinary width of the river above its delta, its current would erode a channel across the bar at least equal in depth to that which it maintains between its natural banks for a great distance above its outlets into the Black Sea. It was also correctly inferred that there would be no extension of the bar beyond the jetties, because a sea current from the north passes from the east by the Crimean coast against the western shore, touching the mouths of the Danube, and flowing into the Mediterranean through the Bosphorus, the Sea of Marmora, and the Hellespont. In 1861, after numerous efforts had been made to effect this confinement of the water by rectangular jetties, it was determined to connect the works and to run two parallel piers nearly 600 feet apart entirely across the bar, and to force the whole volume of water of the Sulina pass to flow into the sea-current between them. The jetty-work with its extension was completed in 1871, and a depth of 20 feet was secured. But an examination of the operations which were at last successful will prove that the engineers did not understand the principle of converging jetties and their proper angulation. Their object was simply to confine the water between parallel walls, supposing that flowing through such contrivances it would dredge a regular channel of the required depth. The idea of a current deflected from a jetty converged from each side at a proper angle to the line of erosion, so as to accumulate an eroding current upon it, which, by its onward gyratory or auger-like motion, would cut out a deep mid-bank channel equidistant from the guiding jetties, seems not to have occurred to their minds; and many engineers of considerable reputation suppose that the removal of the bar was effected by the instrumentality of the *parallel piers.*

A simple inspection of the work demonstrates that the erosion was effected by a part only of the plan, where the principle of convergence was brought into action. (See Plate II.) The bar was removed by an accumulated converged current, produced by a small portion of each jetty where both were directed angularly or diagonally upon a part of the line of erosion. Fortunately

in connecting the upper ends of the jetties at X and W with the beginning of the parallels at Y and Z, their lines were converged, and although they were improperly curved and unequally angulated, instead of having been run straight and at equal angles upon the central channel line *c c*, yet they converged and doubled the force of the lateral currents on the line of the present navigable channel, *which they formed exclusively*, to the deep water of the sea. The only aid given them by the parallels was the protection they afforded as breakwaters against the storms and currents of the Black Sea.

The work of dredging or scouring out the channel was the exclusive work of the portions of the south jetty from *a* to *b*, and of the north jetty from *e* to *d*, which accumulated a gyratory eroding current all along the bottom of the present channel A A, which deviates widely from the line *e e*, intended for its bed.

I dislike to say that this happy effect was the result of the *accidentally* converged connection of the rectangular and parallel jetties. They certainly intended to connect them in order to confine the water and make it flow between the parallels planned to remove the bar, but I think the accumulated current which the convergence of the jetties produced, and which did the *principal part*, if not *the whole of the work of erosion*, was *unintentional* on the part of the engineers. I do not think they intended *the convergence* to produce erosion, because I have heard that they still recommend parallels for the purpose. The irregular winding channel A A which they made proves their ignorance of the whole theory of the proper angulation of jetties, and at the same time it demonstrates conclusively its correctness. If you will examine closely the diagram you will see that the navigable channel A A deviates from its proper midway course at H, and runs diagonally across it to the north parallel at I, which there deflects it eastwardly to J. The divergence given to the channel from its midway course at H, and its dangerous direction to I, is evidently caused by the erroneous angulation of the jetties X *d* and W *b*. The jetty W *b* converges towards the central channel line C C at a greater angle than that made by the opposite north jetty X *d;* and, consequently, *the line of erosion*, or the channel cut by the accumulated currents they produced, is deflected from H to I nearest to the jetty converged with the least angle toward the central line C C. This will be found by experience to be a rule without exception: *Jetties converged at equal angles upon a central line will cause the water-current which they guide to erode a channel, the deepest part of which channel will be upon that central line equidistant from both jetties. If one jetty is run towards it at a less angle than the other, the channel will be cut nearest to the jetty with the least angle.* (See Plate I, Diagram 2.) Consequently, a better plan for the construction of the Danubian jetties would have been to have constructed *two straight jetties*, in 1829, from the extreme northern and southern points of land at that time at *e e*, and to the points *f f* on the outer crest of the bar, and converged at equal angles upon the central line P P. Batture from the river floods would have filled all the spaces between the points of the jetties and their upper connections with the shores, and the lines, 600 feet apart, parallel with the central line of the channel P P; and the sands of "the stormy Euxine" would have extended its shores to the ends of the jetties and against their exterior sides.

It is best to *diverge two sea-walls* at angles equal to the angulation of the jetties from their extreme points. Nature, by its hydraulic system for removing bars and opening harbors at the mouths of great navigable rivers, indicates this plan as the best, and even gives us plainly the proper angulation for jetties, if we choose to imitate or assist her operations. I have heard it said that nature works with parallel banks to deepen the channels of water-currents. This is inferred from the fact that the banks of rivers, whether straight or curved, are usually parallel; hence the conclusion is deduced that in our efforts to remove bars and to deepen channels our guiding jetties or artificial banks ought to be made parallel. This would be true if the premise was correct; for a natural law is always our safest guide when we wish to effect by art what nature performs in obedience to the direction of the Great Creator by the physical forces He has given to her.

But the premise is false; for nature does not guide or deepen the currents of either rivers or seas with parallel banks. On the contrary, I safely and positively assert that *nature works with diagonal jetties exclusively to deepen all channels*, and makes their banks or lateral margins *parallel* by *diagonals* converged to the lines of the direction of the currents, whether they are fresh water or salt, fluviatile or marine. These natural jetties are formed of a variety of materials, rock, clay, wood, or

compounded detritus of various kinds, either undisintegrable by water or less friable and more tenacious and firmly fixed than the banks and bottom bars which oppose the currents which they direct against them. In rivers a diagonally-projecting rock is a natural jetty which will hurl the current against the opposite bank. If the bank which receives the erosive force is composed of strata of soft stone or of earth it will undermine it and wash it away. The Mississippi River, after it receives the Ohio, and leaves its cliffs of rock and enters its vast alluvial area which has all been stratified and rearranged in layers of sand, clay, or mixtures of both, by the floods, and the sleepless and tireless action of its "perpetual motion" for ages, is performing this operation before our eyes to-day of first destroying and then paralleling its banks by diagonal jetties.

Let us examine a single point on the right bank, from which descends a titanic current which strikes a curve in the left bank a mile below and undermines it and swallows it up with everything which grows or which is built upon it. Let us take this destructive, deflective, projecting point, and dissect, anatomize, and make a geological section of it. Its flat top is crowned with a forest of ancient trees and a jungle of cane and bushes, and a variety of vines tying and tangling all its vegetable growth together. Its slope to the water's edge is terraced usually with from three to five steps made by the annual inundations of as many years, marked by successive yearly deposits, the oldest covered with full-grown cottonwood and willow trees, and the newest with saplings and switches of the same growth; and upon the sand strown by the last rise and left bare by the receding flood, we find the downy seeds of these trees clinging to the newly-formed *batture* and springing into life. In time for the next vernal rise of the river they will have grown several feet in height, and covered the sand-bar as thickly as grass in the meadow or wheat in the field, ready to strain the mud from the water of the flood, and to elevate the terrace on which it grows to the height of the one above it. Beneath the water-level we find the sloping bottom of the point projecting diagonally, and all covered with pure sand down to the deepest depression of the river-bed.

Now let us cut through this angulated, guiding, and destructive jetty, and ascertain what is its core, nucleus, or foundation. We will find it at a depth of from 80 to 150 feet resting upon clay. It may be the wreck of a coal-boat, or some other vessel. Usually it will be a cluster of trees and bushes tied together with grapevines, bamboos, or creepers. The river undermines a portion of the primeval forest, and whole clusters of them bound together by vines fall into the water, and by the heavy masses of clay grasped by their roots they are sunk to the bottom where they are occasionally securely fastened, and by catching the water-logged brush, bowlders of rolling clay, and detritus of all kinds lodged against them and compacted into them by the bottom current, they form the foundation of a deflecting jetty which can never be moved. Even if the river cuts its way around one of these sunken tree-rafts, it usually leaves the mass as the supporting foundation of an island. Most of the islands of the Mississippi have been formed by these clusters of trees. Occasionally they float for a while after falling into the strong, deep current which erodes the bank; but where the river widens and shallows its volume over the areas of tenacious clay they "ground" and adhere to the bottom and form the *nuclei* of islands, which act the part of V-shaped jetties with their points *up stream*, which part and deflect the current and *cave in* and curve the opposite shores. Unless jetties are situated in such a position as to prevent the undermining action of these deflected currents, the islands will grow continually at the expense of the banks on either side.

These illustrations will be sufficient to show that the *river-currents* perform their work with diagonal and not with parallel jetties. *The parallel shores are formed by the eddies which whirl on either side of the eroded trough made by the converged and accumulated currents, and which deposit its excavated materials in lines parallel with its course. Sea currents also are operated by diagonals and not by parallels. Nature works with converged diagonal jetties in removing bars at the mouths of rivers, and also those between islands, or between islands and the mainland.* Ever since *the Noachian deluge*, or what geologists term *the Glacial epoch*, Nature has been striving to mingle the deep channels of the great rivers with the deep currents of the seas. This *alma mater* is not pressed for time in performing the work which God has given her to do. For nearly four thousand years she has continued this work with unerring wisdom and omnipotent power, and she has taught us how to aid or imitate her mode of removing bars by showing us that all these rivers enter the sea with *trumpet-shaped* mouths. The diagrams of the Saint Lawrence and each mouth of the Mississippi, and all other great rivers, prove this. They pour their waters into the great deep through divergent

shores, or banks which are natural jetties diverged *seaward*, and converged *upward* towards the inner crest of the bars.

I call the attention of geologists and physical geographers to this important fact, which also deserves the careful consideration of all hydraulic engineers entrusted with the task of removing bars at the mouths of rivers. They not only enter the sea *trumpet-mouthed*, or with divergent banks, but the central line of their currents between the extreme points of land which terminate them is directed at right angles to the sea currents which they enter. Thus the mouths of the Danube open at right angles to the Black-Sea current, which flows from Odessa south across the Sulina mouth to the Bosphorus. The Saint Lawrence opens its vast jaws and discharges its huge volume at right angles into the great Arctic current which descends across it, and also across all the bays and river-mouths from Davis's Straits to Florida. The mighty Amazon, between divergent banks whose extreme sea-capes are 180 miles apart, pours its mammoth tide into the Atlantic current which flows from Cape Saint Roque at right angles to this giant river-mouth, and at the same angulation crosses the mouths of all the rivers on the coasts of the Caribbean Sea and Gulf of Mexico, as it flows on northwardly along the eastern shores of South, Central, and North America, between Cape Saint Roque in Brazil and Cape Sable in Florida, where it forms the Gulf Stream.

All the river-mouths of the whole earth demonstrate the same fact. I will now show the reason for this wise providential arrangement of these river-mouths and the sea-currents with which they mingle, and the operation of this wonderful hydraulic plan of nature to secure the beneficent object of removing the obstructions to the international commerce of the world. The proper study of it will convince any enlightened engineer that any obstruction at the entrances of bays and the mouths of rivers, made by shoals and bars, may be removed by assisting nature in the use of these marine and fluviatile currents, by the proper application of the hydraulic principles which she uses in connecting the deep channels of the rivers with the navigable currents of the oceans and seas. For the removal of all obstructions in bays like the Delaware, Chesapeake, Mobile, and others, the jetties ought to be angulated so as to utilize the scouring action of both the *flow* and *ebb* of the tides, and the influx and outflow of the storm-waters. This can be easily effected by constructing them upon the plan of the diagram for making a ship-channel between Heron Island and the mainland on the west of Mobile Bay. It resembles the worms of Virginia fences making a lane, with the angles of their panels opposite and equal. (See Plate III, Diagram 9.)

Another reason why nature has usually made the mouths of the great rivers and many bays open trumpet-mouthed, and at right angles to the deep-sea currents, is that their currents may be so checked that they may form safe harbors or easy entrances to vessels. If the current of any great river, like the Amazon or Mississippi, instead of entering one of these ocean streams at right angles, were mingled with it at an angle of from $11\frac{1}{4}°$ to $45°$, the *ekmuzesis*, or the suction of the ocean current applied to that of the river, would produce consequences some of which would be disastrous beyond our conception. Eroding velocity and contraction of its channel would certainly ensue, and there could be no safe and easy navigable entrance formed, such as now exists, for the admission of vessels. (See Plate V, Fig. 3.)

In order to show that nature uses this trumpet-mouthed form opened at right angles to these ocean currents to remove the bars of rivers I will take only one example to illustrate this fact. The Southwest Pass of the Mississippi will be sufficient for our purpose; and I select it in preference to the mouths of the Saint Lawrence and Amazon, because the bars once obstructing their outlets have long since been removed by their converging jetties, while the process of the removal of that of the Southwest Pass by the same instrumentality is yet in operation. (See Plate I, Diagrams 3 and 6.)

The mouth of this pass opens directly to the southwest and receives within its divergent jaws or natural banks the full force of the southwestern gales and thunder-gusts, and the great cyclones whose centers move to the northeast. The tides which enter it, and the currents which are driven furiously into it by the tempests, strike its banks which are converged upon the central line of the *inner crest* of the bar. Deflected upon it as they *rush in* from both divergent banks, they are converged and accumulated upon it, and loosen all its friable structure, which is carried out by the ebbing tides and the out-rush of the swollen waters heaped upon the inner crest by the storms; and

while a portion is borne into the ocean current and transported far away, the rest of the wreck of the bar is stranded on either side of the trumpet-shaped outlet, to extend the extreme points of land.

Above the bar the current of the pass pours into the deep trough cut by the concentrated influx of storm-water, and by its lateral eddies parallels the banks up to the new inner crest of the bar, which is advanced continually by the successive tempests and tides towards the deep tropical current of the Gulf which comes from the coast of Texas and Southern Louisiana after curving around Northern Brazil, Guiana, Venezuela, Central America, and Mexico, but whose eddies at the mouths of the passes whirl westwardly opposite to its eastward course. *All currents, whether of rivers or oceans, make eddies along the banks and shores which they erode, and which whirl as counter-currents opposite to the direction of rivers, and of the great equatorial and polar ocean streams.*

Ignorant of this law of all currents, whether of rivers eroding their banks or of oceans wearing away their shores, some of our hydrographic engineers have made it appear that the great tropical current at the mouth of the Mississippi flows westwardly towards Texas. They mistake the surface currents caused by easterly winds, and the eddying counter-current hurled upward by the warm Gulf Stream, which at a depth of several thousand feet is eroding the ancient rocks of the foundations of the continent as it flows on towards the coasts of Alabama and Florida. Vessels and boats *ascending* the Mississippi run next to the curving and caving bends of the river, because there they find counter-currents which bear them up stream; but they know that the river does not flow north but to the south in spite of these eddies.

To enable the Mississippi River and the tropical currents to finish in a year the work of removing the barriers between them, and which Nature unaided will effect slowly but surely in a few centuries, let us assist her a little, guided by the diagram with which she has illustrated her own hydraulic law, or rule of action.

Let us take the diagonal lines of the section of a trumpet, or truncated cone, which designate the natural banks or jetties of the Southwest Pass converged to remove the inner crest of the bar, and reverse their angulation and point them to the outer crest of it, and construct upon them our artificial jetties. Let them be made of piles and fascines as recommended in this essay. The water is all shallow from the extreme points of land to the outer crest of the bar. No stone will be necessary to weigh them down. The wood which forms their frame-work will outlast iron under water either salt or fresh. The *Teredo navalis* and other wood-eaters cannot reach them; for a single annual inundation, a cyclone, or the ordinary gales from the north and southeast, in a year after their completion, will bury them with batture from the river and sand from the Gulf. Two ribs of land 12 feet high above the level of the sea, densely covered with two lines of thrifty and beautiful trees and shrubs, will mark their graves, which will outlast the monuments of Egypt, and remain unmoved until "the trump of Doom" shall rend all tombs. The seaward points of the jetties may be advantageously *diverged* at the same angle with their *convergence* for a variety of useful purposes. They will in some instances gather the force of currents from the sea during storms, and aid by their influx and outflow the erosion of the bar, and the formation of land in the inner angles of the jetties on either side of the navigable channel, and strengthen the whole work; and their divergent sea-points may be suitably formed into light-houses, signal-stations, and forts to guard the pass. It would consume too much time to demonstrate the important fact, which I will simply state, that *by jetties thus angulated* it costs no more to obtain a depth of 60 feet across the bar of the Southwest Pass, or any other over which the same quantity of water flows, than it does to secure a channel 30 feet deep. If by the convergence of the jetty-points on the outer crest of the bar to a distance of 880 yards of each other the channel is scoured 30 feet deep, jetties of precisely the same dimensions and cost brought to *half the distance*, or 440 yards apart, will inevitably dredge one *twice the depth*, or 60 feet. They will force the current to do this without the aid of a dredge-boat; and they will maintain that depth of water without any assistance *forever* as long as it flows between them.

Converged jetties act as a *continual guard* to the channel. They deepen the trough and parallel the sides with its excavated materials. They are buried out of sight in the silt, and they remain concealed as long as the current flows in the trough which they have made. But if a sunken wreck or any obstacle in the channel shifts it to either side, the diagonals are uncovered by its erosion, and they act upon the current as they did at first, and again deflect it to its proper course.

I have not the space to show how the bars of the Amazon, Orinoco, and many other great rivers

have been removed and their deltas swept away by the combined action of the fluviatile and marine currents guided by natural diagonal jetties. The deposits of some of them, like those embraced between the great divergent jaws of the mouth of the Saint Lawrence opened widely to receive and accumulate the high tides of the Arctic current flowing along the eastern shore of British America, have all been scoured out to a bottom of solid rock, walled with the same material, swept bare of all earthy and soluble matters. Deep channels or straits, between continents and islands, are kept open by the deflected currents guided by their angulated shores. (See Plate III, Diagram 9.)

From all these facts the following conclusions are deduced, which I will only have time and space to give in the form of brief practical directions for the guidance of engineers. The same rules, varied by the genius and common sense of those who have to execute the work of controlling and utilizing water-currents, may be applied to any river, and especially to those parts of them which are unobstructed by rocky ledges, and whose beds are composed of sand, clay, and minutely-disintegrated matter, like the Mississippi from Cairo to the Gulf. They may also be applied to those which are obstructed by falls, and flow over beds of stone and between cliffs of rock; but in such cases the erosion caused by the properly-angulated jetties must be aided by blasting and cribwork of wood and stone. I will direct your attention exclusively to the Mississippi River from the mouth of the Ohio to the passes, and give these directions to accomplish the following important objects:

1. To open a navigable channel which at the lowest stage of water will have a depth of 30 feet, and which may be extended up the main tributaries to the Appalachian Chain and the Rocky Mountains.

2. To give permanence to the present banks of the river, and also to preserve those of its islands; or, in other words, to secure the boundary lines of the lands on its banks and islands from being cut and destroyed by the shifting of the current, and to confine the current to an unchanging bed, which will be only altered by being deepened. It will not be permitted to shift laterally, and it will be formed between the present banks, including those of the islands, so that no man's land will be lessened or injured by it. On the contrary, by contracting the width of the river the areas of the land fronting upon it in many instances will be greatly enlarged.

3. To utilize a general levee system which will be permanent, and which will make inundations by overflows, or crevasses by undermines impossible.

Direction 1.

Construct levees of earthwork on the most suitable ground for the purpose and the jetties to protect them simultaneously. The levees should be elevated above the high-water marks of the portions of the river to which they are applied, *and jetties at the same time should be built above every eaving bend*, and not *in it*, extending from the top of the levee to the bottom current of the river. Rows of piles 12 feet apart and standing 8 feet apart in each row, with spike-wrapped fascines felted between, the piles placed and the brush packed, and the whole work girdled as I have already described, should be used where the depth of water does not exceed 40 feet. Their extension to a greater depth will have to be made with mattresses or caissons weighted with stone. The angulation of the jetties must be given to suit circumstances, and especially to direct the current to the points intended, and their effect will depend upon the skill of the engineer. If they are once built on this plan they will last through all future time.

Direction 2.

The river must be confined to a width of *half a mile*. The confinement by the jetties and the distances between their points must be proportioned to the size of each river. The Missouri for a distance of a thousand miles above its mouth must be confined to about a quarter of a mile in width. The Ohio, Arkansas, Tennessee, Red, Kansas, Cumberland, Washita, and Yazoo, and such rivers as the Rio Grande, Alabama, Brazos, and others, must be contracted to widths of from 100 to 250 yards, or to widths proportioned to the volumes of their waters. Channels should be blasted through the ledges of rock forming their falls and shoals, and dams of cribwork of wood and loose stones converged upon the channels to proper distances and at suitable angles. Cribbed-stone jetties must be applied where piles cannot be driven.

To effect this confinement of the Mississippi from Cairo or Saint Louis to the passes, it will not be necessary always to run the jetty points within a quarter of a mile of the central line of the channel they are intended to erode, but they should never approach each other nearer than a half mile. Where the river is very wide, shallow, and straight, it will sometimes be necessary to place them opposite to each other, and to converge their lines to a distance of half a mile between their points. But often short jetties, properly angulated, will greatly reduce the width of the river below them. In every instance where a properly-constructed jetty is run into the bottom current at an angle of 45°, it will deflect the current entirely across the bed against the opposite shore, unless the current deflected from another jetty extended from that shore strikes it diagonally before it reaches it. This is an important fact which should never be forgotten by hydraulic engineers, who must be required to *mingle the currents to prevent either of the two from reaching the shore opposite to its location.* The main object is to form them into an accumulated eroding current to deepen the bed, and to make batture against the banks. A properly-constructed jetty on one bank will certainly destroy the bank on the opposite side against which it points the current, unless another is suitably placed for its protection.

Direction 3.

Where it is necessary to scour a deep channel nearer one shore than the other, as in the case of a city front with its wharves, the jetties above the wharves must be deflected from the bank at very small angles, while those which guide the water from the opposite bank must have angles more obtuse, and in some instances they must have the maximum angulation of 45°. It must be remembered that the *minimum* angulation in all cases is $11\frac{1}{4}$°, and the *maximum* 45°, which is easily demonstrated by experiment. The angles of jetties to *turn cut-offs* like that at Vicksburg, and to close them, or to stop crevasses, must always be angulated from $22\frac{1}{2}$° to 45°. (See Plate IV, Diagrams 1 and 2.

Direction 4.

To protect islands, construct at the upper end of each a V-shaped jetty with its point up stream, which will part the river current and deflect an eroding current toward each of the opposite banks. The eddies around the wings of the jetty will enlarge the island continually, while the currents which these wings deflect will undermine and destroy the banks unless jetties are placed upon them to catch the deflection and *reflect* it to a safe distance. If it is desirable to enlarge the island, the jetties on the opposite banks should be so angulated as to mingle the currents below it. It will extend until it reaches the point where the converged waters meet. If it is necessary to destroy the island, construct jetties on both banks above and opposite to it, to guide the currents against its sides from the upper to the lower end.

Direction 5.

To close a cut-off, bayou, or crevasse, first construct a jetty above it to deflect the current from its outlet from the river and form an eddy in it, and, if it is necessary, which will seldom be the case, assist the operation by a row of piles and fascines if it is shallow, or by sinking into it a connected raft of large trees with all their branches upon them down to the bottom if it is deep. I am not prepared to say precisely where such a work should be constructed to restore the river to its former channel in front of Vicksburg, as I have not examined the locality since the river has cut its way through the neck of the peninsula and left the city on the eastern curve of a crescent lake, and I have seen no chart of it since the destructive change occurred; but I am very confident that one or more jetties, constructed as all jetties should be, *at low water*, and at a suitable point on the right bank above the gap made by the new channel, would turn the whole river permanently against the rocks of the left bank and into its former bed. I cannot give an estimate of what it would cost the United States Government to make this improvement for this important harbor, as I have seen no topographical survey of it since the disaster happened, but I do not think that it would be much.

With this general outline of the titanic plan for chaining the mammoth river and utilizing its mighty current, I will close this essay, which I fear has been tedious, notwithstanding the omission of all specific details not necessary for its explanation.

To lower the whole bed of the Mississippi effectually, *the lowest bar should be removed first, and then those above should be destroyed successively or simultaneously* as high up as it is proposed to make it navigable, and to prevent its inundations. The river current, compelled to act permanently in a fixed channel, will deepen continually from age to age until its bed is conformed to the general slope of the continent from its highest navigable tributaries to its mouth in the Gulf. The inclination or dip of the strata of its bed-rock from the mountain crest to the deepest depressions of the Gulf determines the angulation of this slope. It would be madness to straighten its curves. Its velocity, caused by the earth's revolution on its axis, with its centrifugal force acting directly upon its vast volume, hurling it directly from the direction of the North Pole towards the Equator, would render it unnavigable and uncontrollable. Bends, changing this *direct* or *rectilinear action*, check its force. Our object should be to give fixedness to property on its banks, and to increase the area of its arable alluvial soil while we prevent its overflows, and at the same time make it safely and permanently navigable.

The excellence of this plan for controlling water-currents directed to cut channels of geometrical shapes by properly angulated jetties is made apparent by experiment. No dredging is necessary where the materials of the bottom are not more solid than the alluvium of the rivers and the sands and clays of our southern shores. In all places where these jetties are properly applied to make either river or sea currents deepen channels through such materials, in almost every conceivable instance of their application, they will form areas of *batture*, or new land, which will be worth much more than the entire cost of their construction. In order that these principles may be better understood and applied, I have directed the attention of engineers to the Mississippi, Lake Pontchartrain, and a few other points for the purpose of illustration. But if they possess ordinary genius, with even but little invention, they can easily vary and apply the same principles of angulation and *ekmuzesis* to any river, harbor, or marsh where there is water to employ and control. They who still cherish the absurdity taught me in my boyhood, that water, unlike other fluids composed of globules of atoms, *cannot be reflected*, of course cannot understand them, and will not attempt to utilize them.

CONCLUSION.

If the facts which I have presented, with the theories based upon them, in this essay, have given it the appearance to some minds of a harsh criticism upon the plans of hydraulic engineering applied by Sir Charles Hartley and other eminent engineers to the rivers and harbors of Europe and America, I say in all sincerity that I have not intended to detract any ray from their deserved renown, or to diminish the debt of gratitude due to them by mankind for their useful services. My object has been to give the improvements to all plans for controlling and utilizing the currents of rivers and seas which newly-discovered facts and useful inventions have suggested. I honestly desire to facilitate the tasks of these meritorious laborers for the welfare of the world, and to save them and those who will succeed them from much unnecessary toil and expense in their operations by presenting them with improvements which will make similar works, and others on a grander scale, cheaper, easier, and better. The latest discoveries made in the science of zoölogy, and in the arts of photography, telegraphy, and steam navigation only enhance the fame of Cuvier, Daguerre, Morse, and Fulton, and render their memories more dear to all nations as benefactors of the human race. I will only add that I tested all these inventions for controlling and utilizing water-currents, and which were made in order to cheapen the vast and permanent works for which they are designed, by the most careful and satisfactory experiments before I ventured to publish them in these lectures for the welfare of mankind.

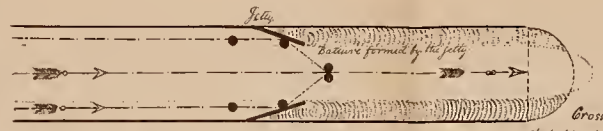
May the God of all wisdom and power give them grace to use them wisely and successfully.

T. 7
R. XIV. E
T. 7
R. XV. E
HONEY
Indian
Devil Tiger Cr.
R. XVI. W

Sections of Hardee's Map
of Louisiana, showing the three parts of a plan of hydraulic engineering for
the Drainage of the City of New Orleans, & the Desiccation & irrigation of Swamps and Marshes;
the improvement of Lake Pontchartrain, and the prevention of its inundations; and the removal
of the Bars of the Mississippi, and the protection of its banks against undermines and overflows.
By
E. Fontaine.

Plate II

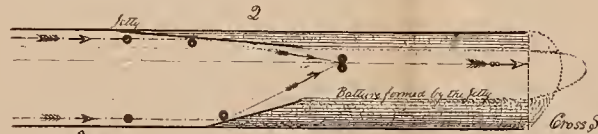
Diagram 1



Cross Section the deepest part on the central line of erosion.

The guidance of water currents on the principle of the angle of incidence is equal to the angle of reflection, so as to produce an accumulated erosive force on a central line, equidistant from parallel banks, and the points of guiding jetties converged upon that central line at equal angles.

2



Cross Section – Shewing the deepest part next the jetty with the smallest angle to the line of erosion.

The guidance of a water current on a line of erosion nearer to one bank than the other by jetties converged upon it at unequal angles. The deepest part of the eroded Channel will be next to the jetty with the least angle. It is necessary to construct jetties with this angulation where it is desirable to have deep water near wharves and landings.

4

Cross Section made by converged jetties.

Diagram shewing the action of converged jetties in burying or removing Sunken vessels, logs mud lumps & other obstructions, guiding the water centrally with accumulated force, and acting as perpetual guards and scourers of the channel, so as to make all mechanical dredging unnecessary.

5

Diagram shewing that parallel jetties will not guide water currents so as to form regular Channels with uniform Cross-Sections, and to remove Sunken ships, logs mudlumps and other obstacles to safe navigation. Their action always requires the aid of dredge boats, or other mechanical contrivances for making navigable water ways.

3

The object of this Diagram is to explain Nature's method for removing bars at the mouths of rivers, and to connect their navigable channels with the deep currents of the sea. Their mouths are Trumpet Shaped, or the outlines of the shores of their mouths are sections of Cones. They diverge Seaward, & converge Riverward or upstream upon the inner crest of their bars. The inflowing storm or tidal waves strike the divergent banks, and are converged by reflection upon a line equidistant from both shores or nearest the one which is diverged at the least angle from a central flow clashing upon the bar, & the accumulation thereby raises the bar, & the outflowing current clears & carries materials away. & the deepest channel is kept over the bar.

6

This Diagram is intended to shew how Nature's plan for removing bars by natural banks properly angulated may be utilized, by constructing artificial banks or jetties converged at suitable angles on the outer crests of bars. The accumulation of the strong current of the Mississippi or any other river will not only remove the outer crest but form a channel across the entire area of any stable bar. If there is a constant inflowing and outflowing tide more than one pair of divergent jetties will be necessary, & the method recommended for removing tidal bars will have to be used.

B. Fontaine del

Plate III

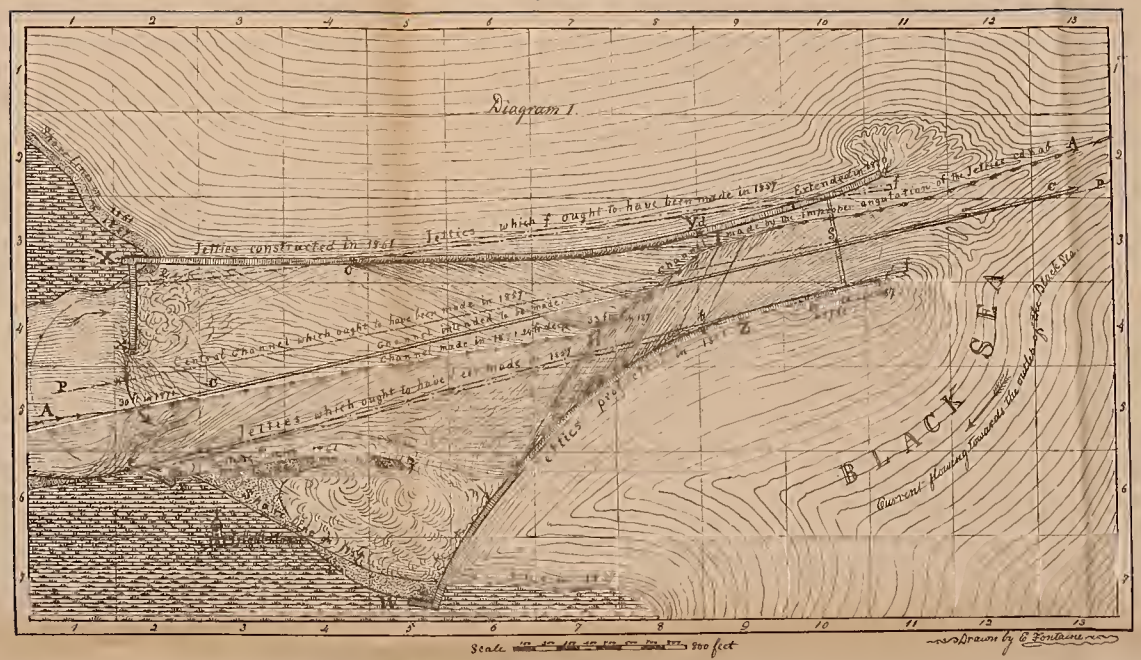
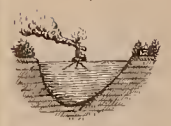


Diagram 2.



Cross Section of the Channel at S made by the Jetties C d' & C b'.

Dia. 3.

Cross Section of a Channel at S which would have been made by the Jetties E f & E f.

Map of the Sulina Mouth of the Danube.

The Map is intended to show how a Channel of the depth of 24 feet was obtained across the bar by the application of Jetties; and also to demonstrate the errors made in their angulations, and to exhibit a diagram of a better plan for securing a straight & uniform Channel a cross section of whose trough at any point across the bar would have been the arc of a circle. The Channel AA was formed by the accumulated current made by the convergence of the Jetties Xd' and Wb' from C to d, X from a to b. It was deflected from its proper course CC and curved from X to I by the Jetty from a to b having a more obtuse angulation to the central Channel-line CC than the North Jetty from C to d'. This deflection of the current of the Danube near the North Jetty at I caused the deepest part of the navigable Channel to be formed North of the central line CC, and too near the Jetty Xd' as represented by the Cross-section of its trough at S. Jetties properly angulated and constructed as marked by the dotted parallel lines E f & E f would have accumulated an eroding current upon the central dotted line I I. which would have scoured and kept open perpetually a straight and uniform Channel 30 feet deep all of the Cross Sections of which would have been the arcs of circles as represented by the Diagram of the one at S. This would have rendered unnecessary the objectionable rectangular Jetty Xx, and also the portion of the South Jetty from w to a constructed at right angles to the current of the Danube. Such Jetties always require additional rectangular extensions, as those made at X and W to prevent the lateral expansions of the Currents which they check or dam, but which they do not deflect and guide, and which erode their connections with the banks or shores, and but for such L or J shaped extensions of their bases sever them and form crevasses, and leave the Jetties separated from the land as islands in the rivers or the harbors. The erroneous construction of the Danubian Jetties in 1861 by their deflection of the water caused the deep gorges in the shore at x' and W w' and the bar at z.

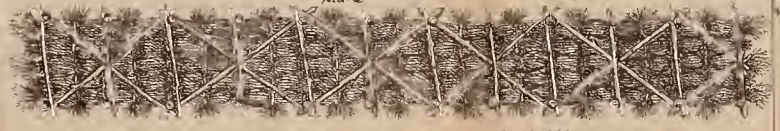
Plate III

A front and vertical view of a jetty or breakwater made of piles and fascines. The piles are trees with the bark on them driven with the butts down and sharpened. The fascines are made of willow brush or limbs of piles.

Diagram 1

The piles are driven every eight feet in rows twelve feet apart. The fascines are packed closely in alternate floors parallel and at right angles to the rows of piles, and girded with poles 15 & 24 feet long crossed & nailed to the piles.

Dia. 2



3

Fascine of willow brush 15 feet long. Fascines of this kind adhere to the bottom & to each other by their barbs, and when properly packed obviate the use of stone.

4

Pile.

5

Tie for the fascine made of three sticks 8 feet long barbed & sharpened, & wrapped with a long willow limb.

6

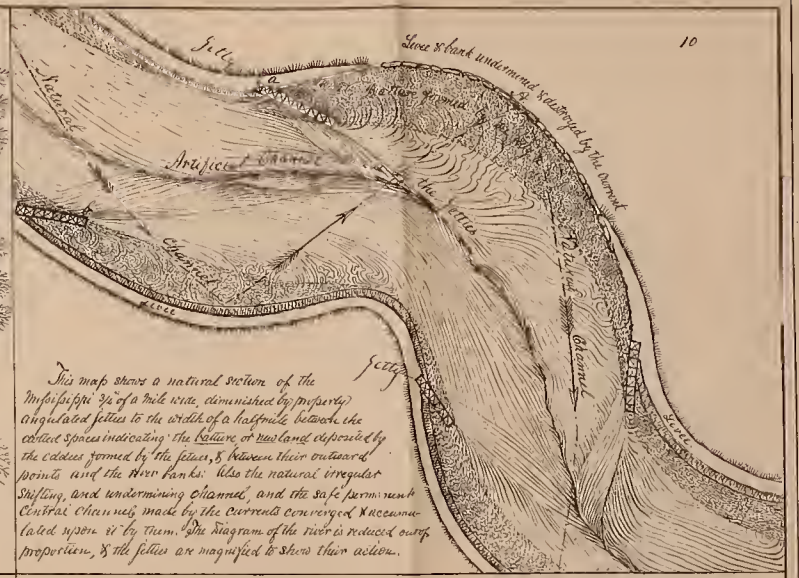
Cypress tree for a pile.

7

8

Limb suitable for making a barb for the fascine

10



This map shows a natural section of the Mississippi 3/4" of a mile wide, diminished by properly angulated jetties to the width of a half mile between the dotted spaces indicating the batture or new land deposited by the eddies formed by the jetties, & between their outward points and the river banks. Also the natural irregular shifting, and undermining channel, and the safe permanent central channel, made by the currents converged & accumulated upon it by them. The diagram of the river is reduced out of proportion, & the jetties are magnified to show their action.

9

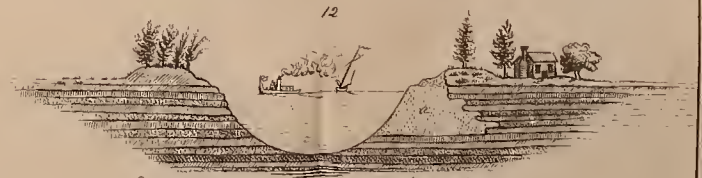
A Diagram of Jetties for removing bars, or opening navigable channels between islands, or at the mouths of rivers, or in any other place where there are tidal currents, or currents which ebb & flow, or counter-currents, or those which move in opposite directions. The jetties are so angulated as to accumulate the ice & outflowing waters & make both scour & channel. The works may be curved & extended to suit circumstances. By this plan the Alabama River can be conducted through Mobile Bay into the Gulf of Mexico. I recommend the above drawn jetties of piles & filled fascines for such works

Drawn by G. Fontaine

11

A natural cross-section, or profile of the river-bed at A undermining the bank by washing out the sandy layers, and leaving the strata of clay without support. The natural zig-zag current is perpetually eroding one bank or the other.

12



An artificial cross-section of the river at A made by the central current converged & accumulated by the jetties a & b. Fig 10 Showing its new bed the arc of a circle whose greatest depth is in the middle of the river. The surface of the water is reduced to the width of a half mile, and lowered by the removal of the bars below by converged jetties whose application is supposed.

Drawn by G. Fontaine

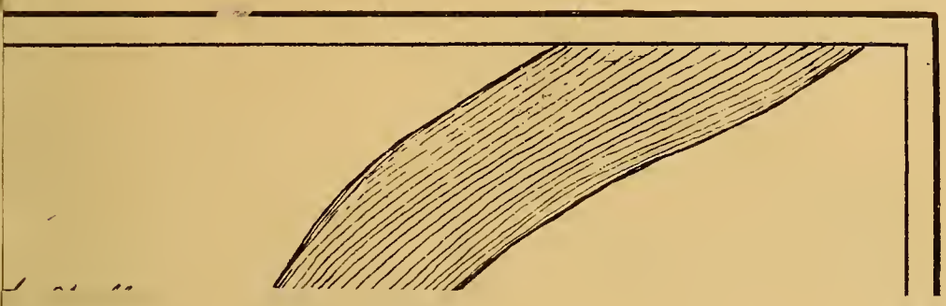


Plate IV

Diagram 1

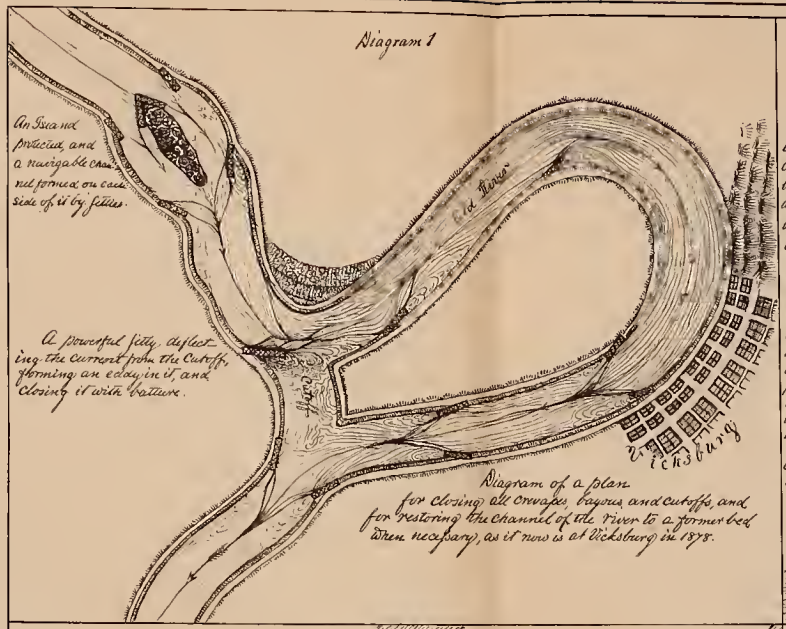
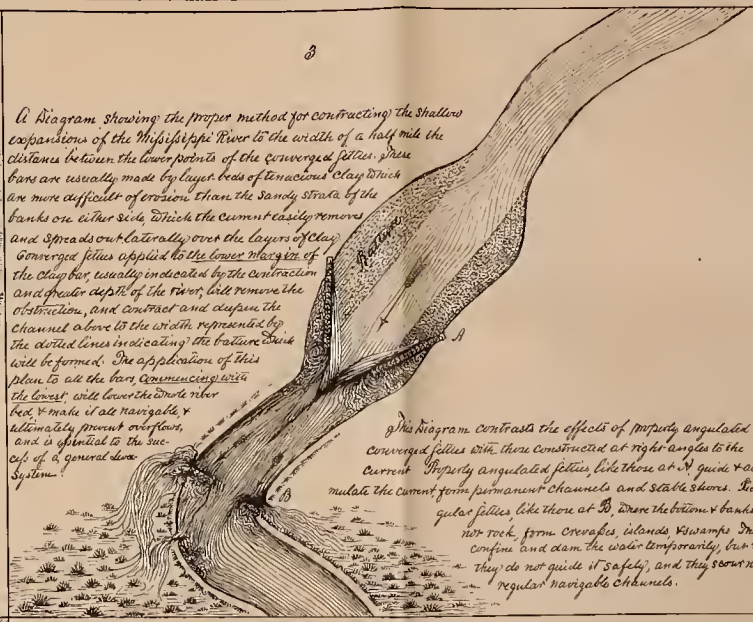


Diagram of a plan for closing all Crevasses, bayous and Cutoffs, and for restoring the Channel of the River to a former bed when necessary, as it now is at Vicksburg in 1878.

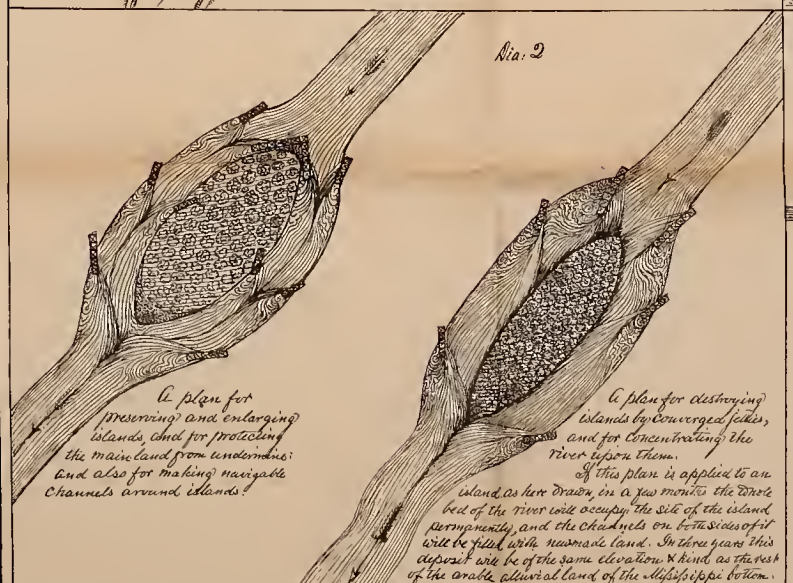
3



A Diagram showing the proper method for contracting the Shallow expansions of the Mississippi River to the width of a half mile the distance between the Lower points of the Converged Jetties. These bars are usually made by layers of tenacious clay which are more difficult of erosion than the Sandy Strata of the banks on either side which the current easily removes and spreads out laterally over the layers of clay. Converged Jetties applied to the lower margin of the Clay bar, usually indicated by the contraction and greater depth of the River, will remove the obstruction, and contract and deepen the channel above to the width represented by the dotted lines in red, creating the batture which will be formed. The application of this plan to all the bars commencing with the lowest, will lower the whole river bed & make it all navigable, & ultimately prevent overflows, and is essential to the success of a general levee System.

This Diagram contrasts the effects of properly angulated converged Jetties with those constructed at right angles to the current. Properly angulated Jetties like those at A guide & accumulate the current, form permanent Channels and stable shores. Perpendicular Jetties like those at B, where the bottom & banks are not rock, form Crevasses, islands, & swamps. They confine and dam the water temporarily, but they do not guide it safely, and they secure no regular navigable Channels.

Dia: 2



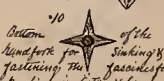
A plan for preserving and enlarging islands, used for protecting the main land from undermining; and also for making navigable Channels around islands.

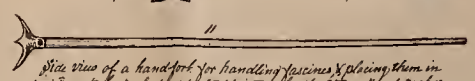
A plan for destroying islands by Converged Jetties, and for Concentrating the river upon them.

If this plan is applied to an island as here drawn in a few months the whole bed of the river will occupy the site of the island permanently, and the Channels on both sides of it will be filled with reclaimed land. In three years this deposit will be of the same elevation & kind as the rest of the arable alluvial land of the Mississippi bottom.

4

Vertical Section of the Aqueduct & a Sewer for Drainage.





Side view of a hand fork for handling fascines & placing them in position to be pressed and fetted together by the Steam Brushpacker, which should weigh 100 pounds, and be worked like a Tilt hammer.

Drawn by C. Fontaine.

Fig 4.

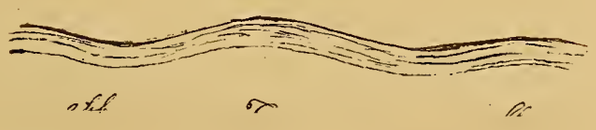


Plate V

Fig 4

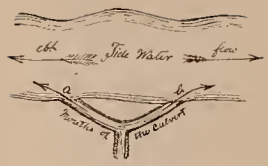


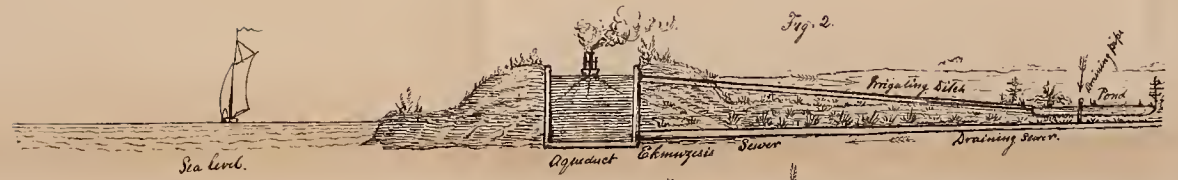
Diagram shewing the proper construction of the mouths of draining Culverts and Sewers which connect with the main currents of Creeks, inlets, or Bays.

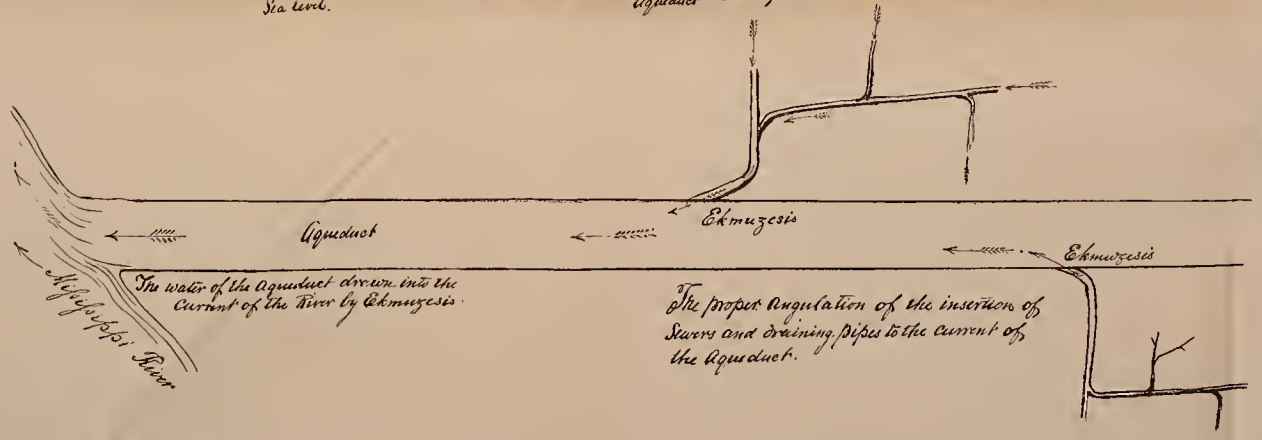
Fig. 1

The inefficient erosive power of parallel jettues illustrated by a cylindrical pipe attached to a fire-hose.

The scouring force of converging jettues illustrated by the action of a conical pipe attached to a fire hose.

Fig. 2.





The proper Angulation of the insertion of Sewers and draining Pipes to the current of the Aqueduct.

Fig. 3.

This Diagram shews the angulation to give the entrance of an aqueduct into a Sea Current to make it drain a salt marsh or fresh-water swamp by Ekmuzesis.

CONTRIBUTIONS

TO THE

SCIENCE OF HYDRAULIC ENGINEERING.

BY

EWD. FONTAINE,

PROFESSOR OF THEOLOGY AND NATURAL SCIENCE, MEMBER OF THE NEW YORK HISTORICAL SOCIETY, THE HISTORICAL SOCIETY OF MARYLAND, &c., AND OF THE ACADEMIES OF SCIENCE OF BALTIMORE, NEW ORLEANS, &c., AUTHOR OF "HOW THE WORLD WAS PEOPLED," &c.

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